

**Quarterly Report
Massachusetts Institute of Technology
GAGE Facility GPS Data Analysis Center Coordinator**

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Period: 2019/10/01-2019/12/31

Table of Contents

Summary	2
GPS Analysis of Level 2a and 2b products.....	2
ITRF2014 transition.....	2
Level 2a products: Rapid products.....	2
Level 2a products: Final products	2
Level 2a products: 12-week, 26-week supplement products.....	3
Analysis of Final products: September 15, 2019– December 21, 2019	3
GLOBK Apriori coordinate file and earthquake files	12
Snapshot velocity field analysis from the reprocessed PBO analysis.	12
Earthquake Analyses: 2019/09/15-2019/12/15	21
ANET Processing	21
References.....	23

Summary

Under the GAGE2 Facility Data Analysis subaward, MIT has been processing SINEX files Central Washington University (CWU) and aligning them to the GAGE NAM08 reference frame. In this report, we show analyses of the data processing for the period 2019/09/15 to 2019/12/31, time series velocity field analyses for the GAGE reprocessing analyses (1996-2019). Several earthquakes were investigated this quarter but none generated coseismic displacements > 1mm.

Analysis files (pbovel files and offset files) are generated monthly and sent via LDM in the middle of each month.

We continue to process ANET data. Starting GPS Week 2021 (2018/09/30) only CWU solutions are included. These solutions are in then ANT14 frame as defined in the ITRF2014 plate motion model [*Altamimi et al., 2017*].

GPS Analysis of Level 2a and 2b products

ITRF2014 transition

The ITRF2014 re-processing analysis has been completed and the transition from the NAM08 system to NAM14 has been completed. The NAM08 and IGS08 distributions will be discontinued on January 1, 2020.

Level 2a products: Rapid products

Final and rapid level 2a products have been in general generated routinely during this quarter for the CWU solutions. 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 JPL orbits and clocks. Finals and rapid solutions are now being generated in the IGS14 system. In this quarter 2073 stations were processed which is 26 less than last quarter. In addition up to 60 sites were processed in the ANET solutions, 2 more than last quarter.

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 CWU for the main GAGE2 Networks of the Americas stations (NOTA). The delivery schedule for these products is also unchanged.

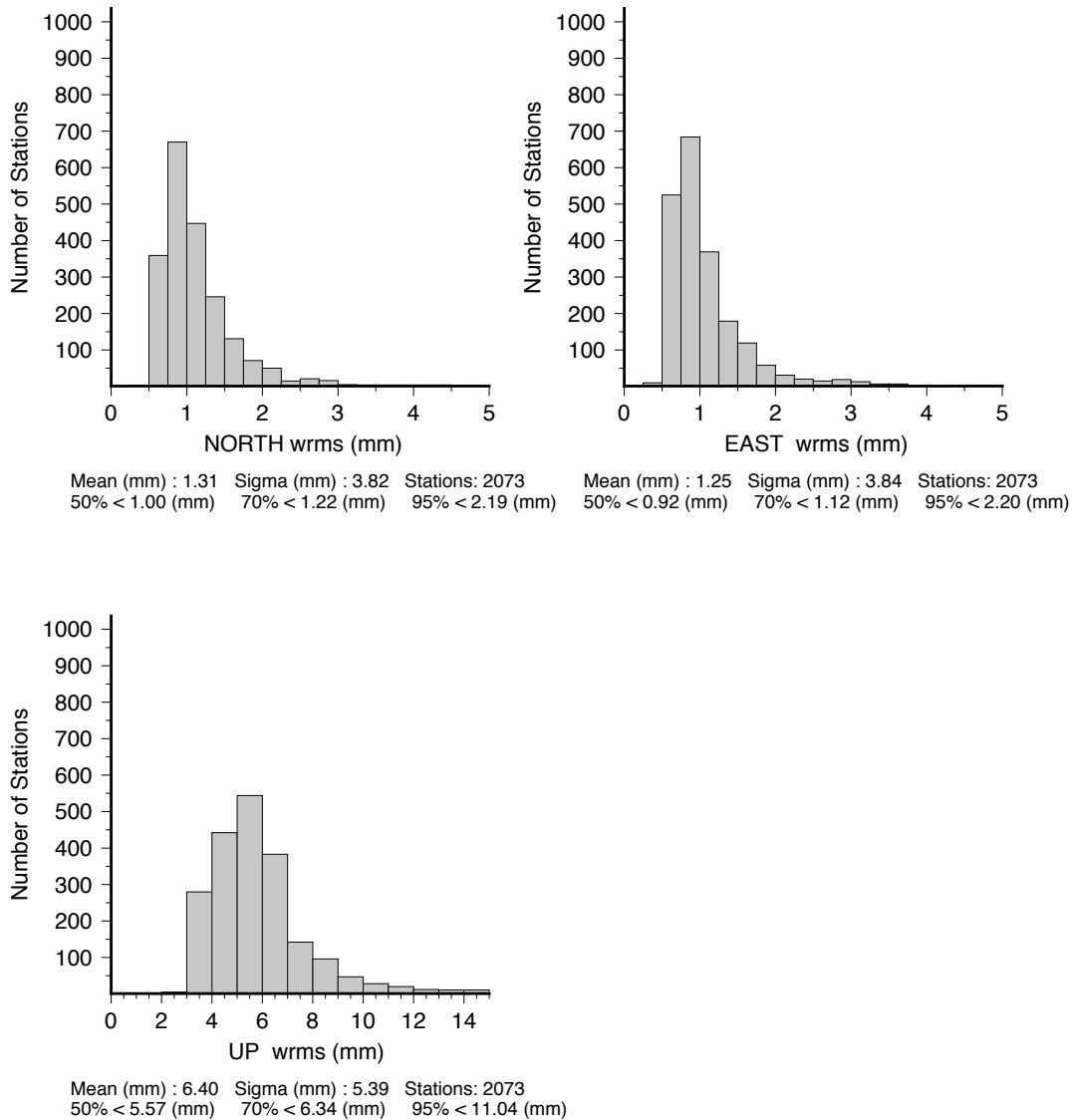
Analysis of Final products: September 15, 2019– December 21, 2019

For this report, we generated the statistics using the ~3 months of CWU results between September 15, 2019 and December 21, 2019. These results are summarized in Table 1 and figures 1.

For the three months of the final position time series generated by, 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. Table 1 shows the median (50%), 70% and 95% limits for the RMS scatters CWU. The detailed histograms of the RMS scatters are shown in Figure 1 CWU.

Table 1: Statistics of the fits of 2073 stations for CWU analyzed in the finals analysis between September 15, 2019 and December 21, 2019. Histograms of the RMS scatters are shown in Figure 1.

Center	North (mm)	East (mm)	Up (mm)
Median (50%) CWU	1.00	0.92	5.57
70% CWU	1.22	1.12	6.34
95% CWU	2.19	2.20	11.04



Scatter-Wrms Histogram : FILE: CWU_FIN_Y2Q1.sum

Figure 1: CWU solution histograms of the North, East and Up RMS scatters of the position residuals for 2099 stations analyzed between September 15, 2019 and December 21, 2019. Linear trends and annual signals were estimated from the time series.

For the CWU 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 2-7. The values plotted are given in [CWU_FIN_Y1Q4.tab](#).

There are 2073 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 CWU_FIN_Y2Q1.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	91	1.1	0.40	1.5	0.54	7.9	0.59	16.66
1NSU	91	0.9	0.36	1.1	0.46	5.6	0.52	15.92
1ULM	87	0.9	0.36	1.0	0.42	7.0	0.62	16.52
7ODM	85	1.1	0.39	0.9	0.38	5.9	0.54	18.67
...								
ZDV1	91	1.0	0.37	0.9	0.41	5.8	0.56	16.55
ZKC1	91	1.0	0.36	0.9	0.40	6.2	0.58	16.55
ZLA1	91	1.2	0.46	1.0	0.44	6.3	0.61	16.55
ZLC1	90	0.9	0.32	0.8	0.34	5.6	0.54	16.78
ZME1	91	1.0	0.37	1.0	0.45	6.6	0.62	16.78
ZMP1	91	1.0	0.34	0.9	0.41	6.6	0.63	17.02
ZNY1	91	1.0	0.36	0.8	0.35	5.5	0.52	16.93
ZOA1	91	0.8	0.29	0.7	0.30	4.4	0.43	17.47
ZSE1	91	0.8	0.28	1.1	0.48	4.7	0.46	16.93
ZTL4	91	0.9	0.35	1.3	0.57	6.0	0.56	17.13

Table 2: RMS scatter of the position residuals for the CWU solution between September 15, 2019 and December 21, 2019 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	0.89	0.84	5.00	874
NUCLEUS	0.84	0.81	5.01	204
GAMA	0.83	0.86	6.23	13
COCONet	1.52	1.64	7.57	70
USGS_SCIGN	0.91	0.84	5.08	114
Expanded	1.11	1.01	6.22	798
70%				
PBO	1.10	1.02	5.64	
NUCLEUS	0.96	0.94	5.62	
GAMA	0.95	0.90	6.64	
COCONet	1.67	1.84	8.62	
USGS_SCIGN	1.07	1.01	5.77	
Expanded	1.31	1.19	6.90	

95%			
PBO	2.17	1.94	8.90
NUCLEUS	1.79	1.54	10.31
GAMA	1.25	1.10	7.86
COCONet	2.81	3.13	18.75
USGS_SCIGN	2.04	1.81	11.95
Expanded	2.41	2.37	13.51

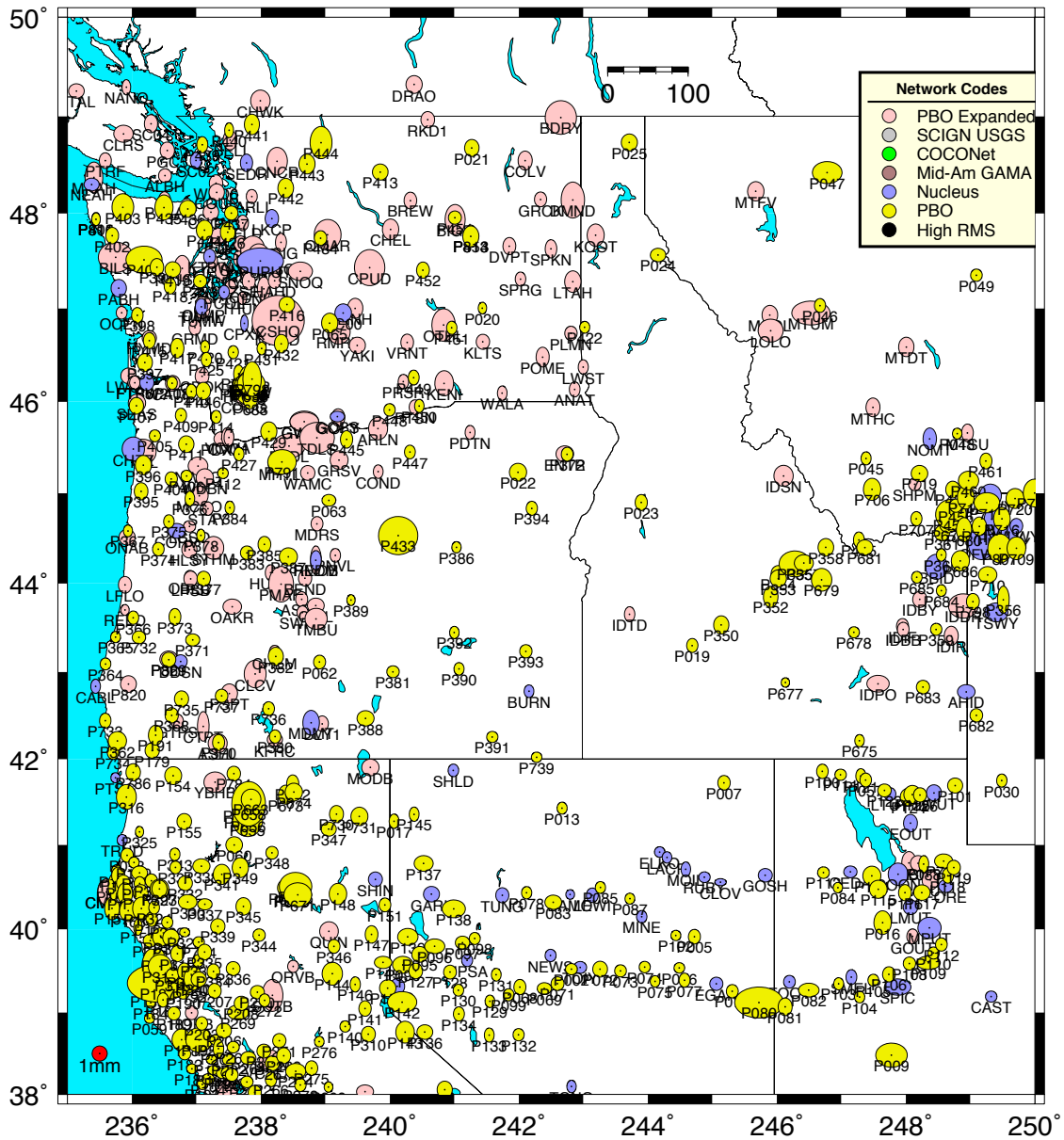


Figure 2: Distribution of the RMS scatters of horizontal position estimates from the CWU analysis for the Northern Western United States. The color of the ellipses that give the north and east RMS scatters denotes the network given by the legend in the figure. The small red circle shows the size of 1 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.

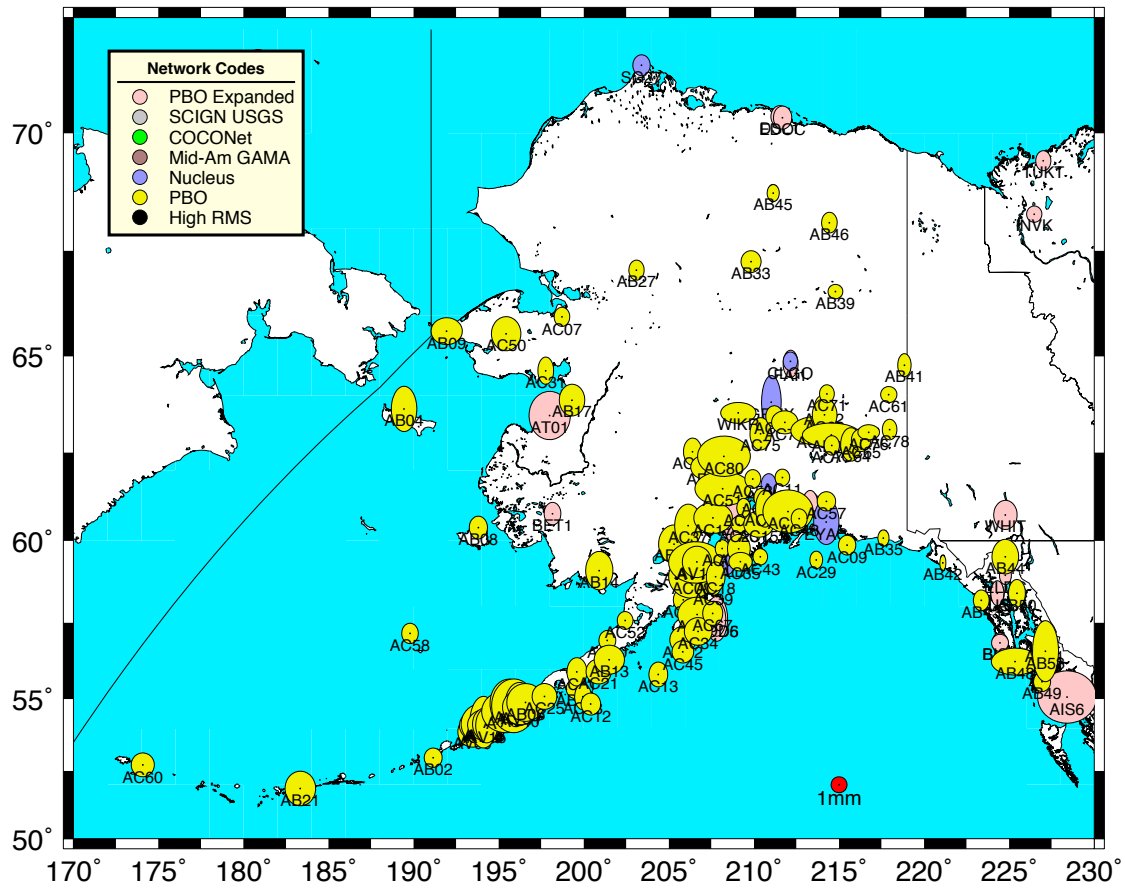


Figure 4: Same as Figure 4 except for the Alaskan region.

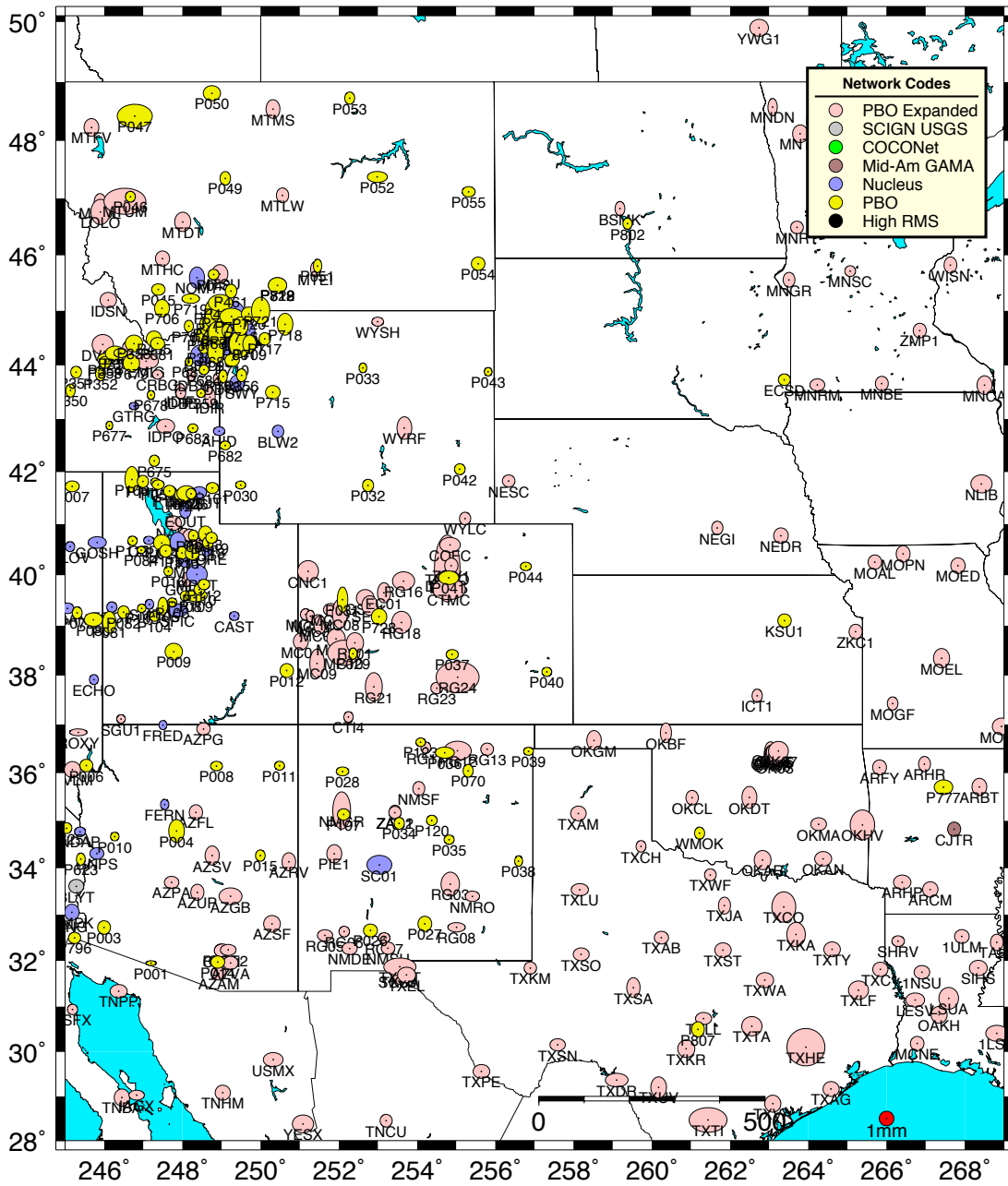


Figure 5: Same as Figure 4 except for the Central United States

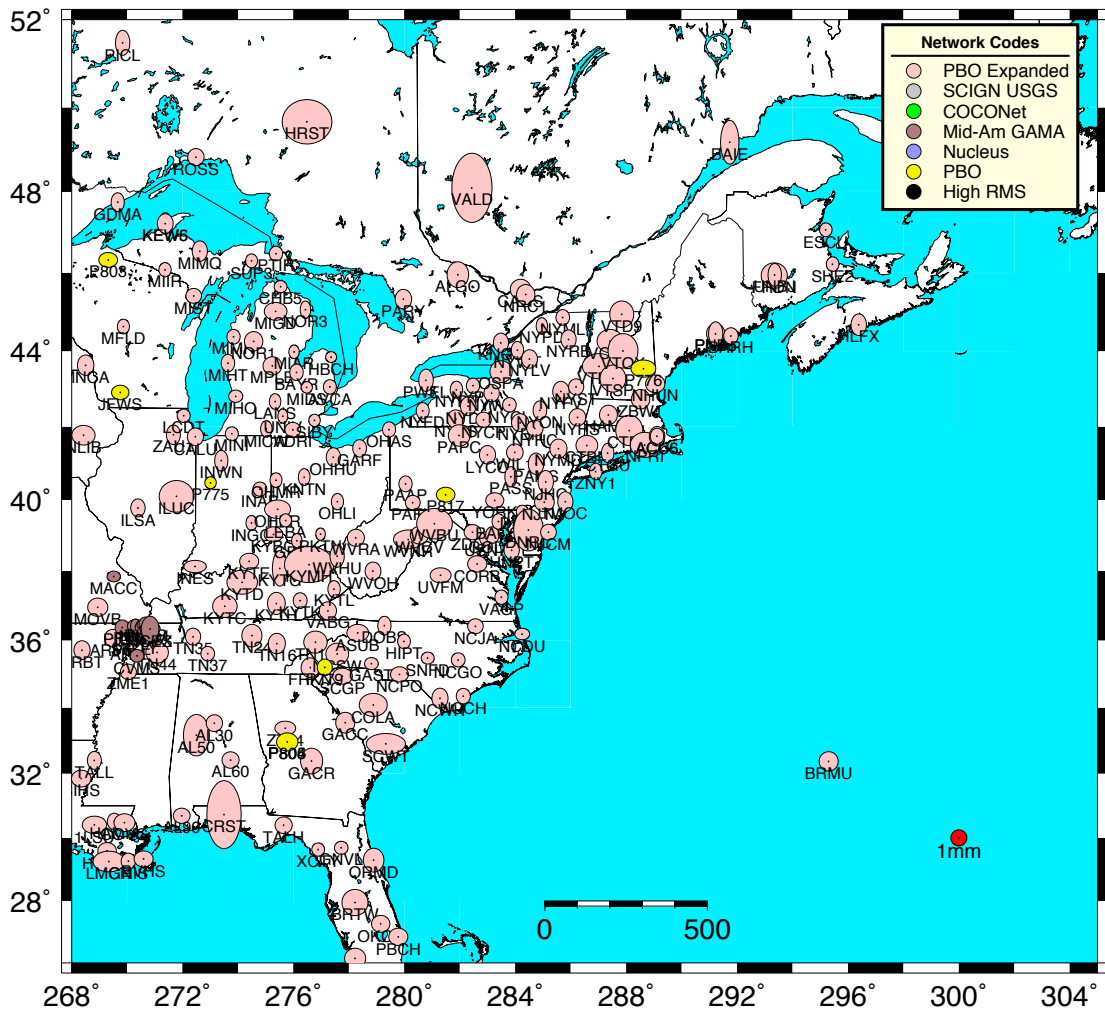


Figure 6: Same as Figure 4 except for the Eastern United States

For this quarterly report, we generate velocity estimates for the reprocessed results and the current GAGE analyses that are in the NAM14 reference frame using the CWU analysis. There are 2628 stations in the CWU solution. 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 [cwu_nam14_191221.tab](#). The velocity estimates are shown by region and network type in Figures 8-14. The color scheme used is the same as Figures 2-7. The snapshot velocity field file for CWU is [cwu_nam08_191221.snpsvel](#).

Table 3: Statistics of the fits of 2628 stations analyzed CWU in the reprocessed analysis for data collected between Jan 1, 1996 and December 21, 2019

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
CWU	1.39	1.34	6.13
70%			
CWU	1.75	1.68	6.96
95%			
CWU	3.77	3.55	12.14

In Figures 8-14, 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.

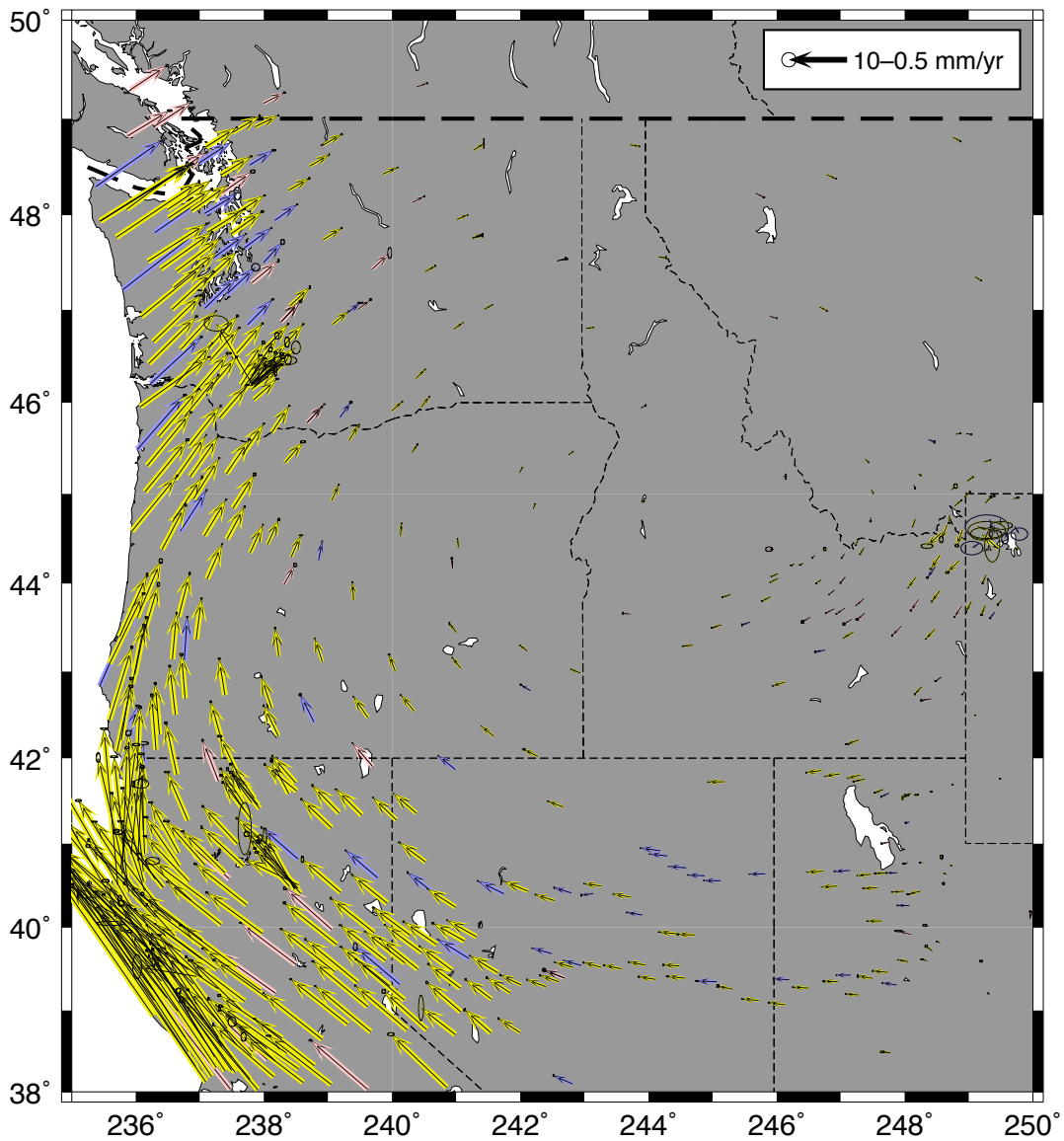


Figure 8: Velocity field estimates for the Pacific north-west from the CWU solution generated using time series analysis and the FOGMEX error model. 95% confidence interval error ellipses are shown. The color scheme of the vectors matches the network type legend in Figure 4. Only velocities with horizontal standard deviations less than 2 mm/yr are shown (this value is reduced from previous reports due the improved velocity sigmas).

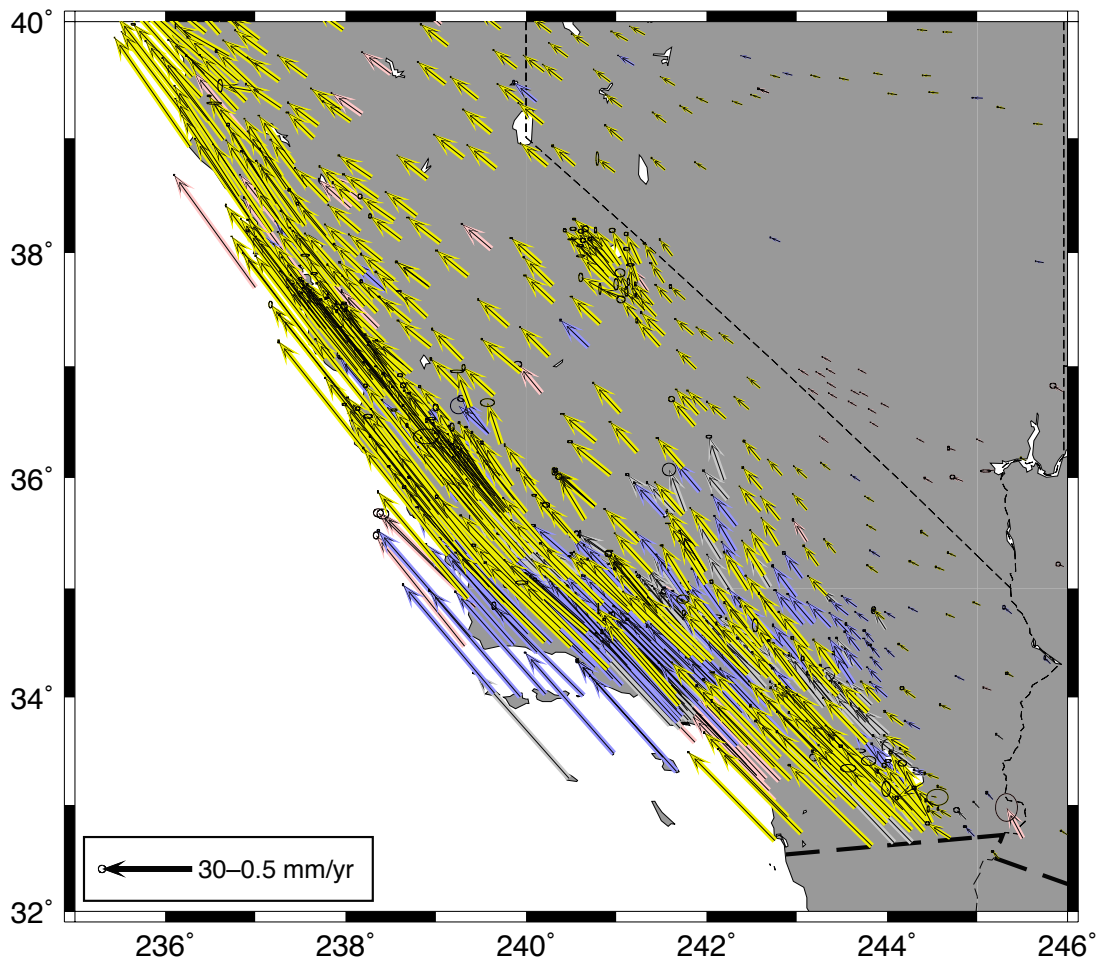


Figure 9: Same as Figure 8 except for South Western United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown.

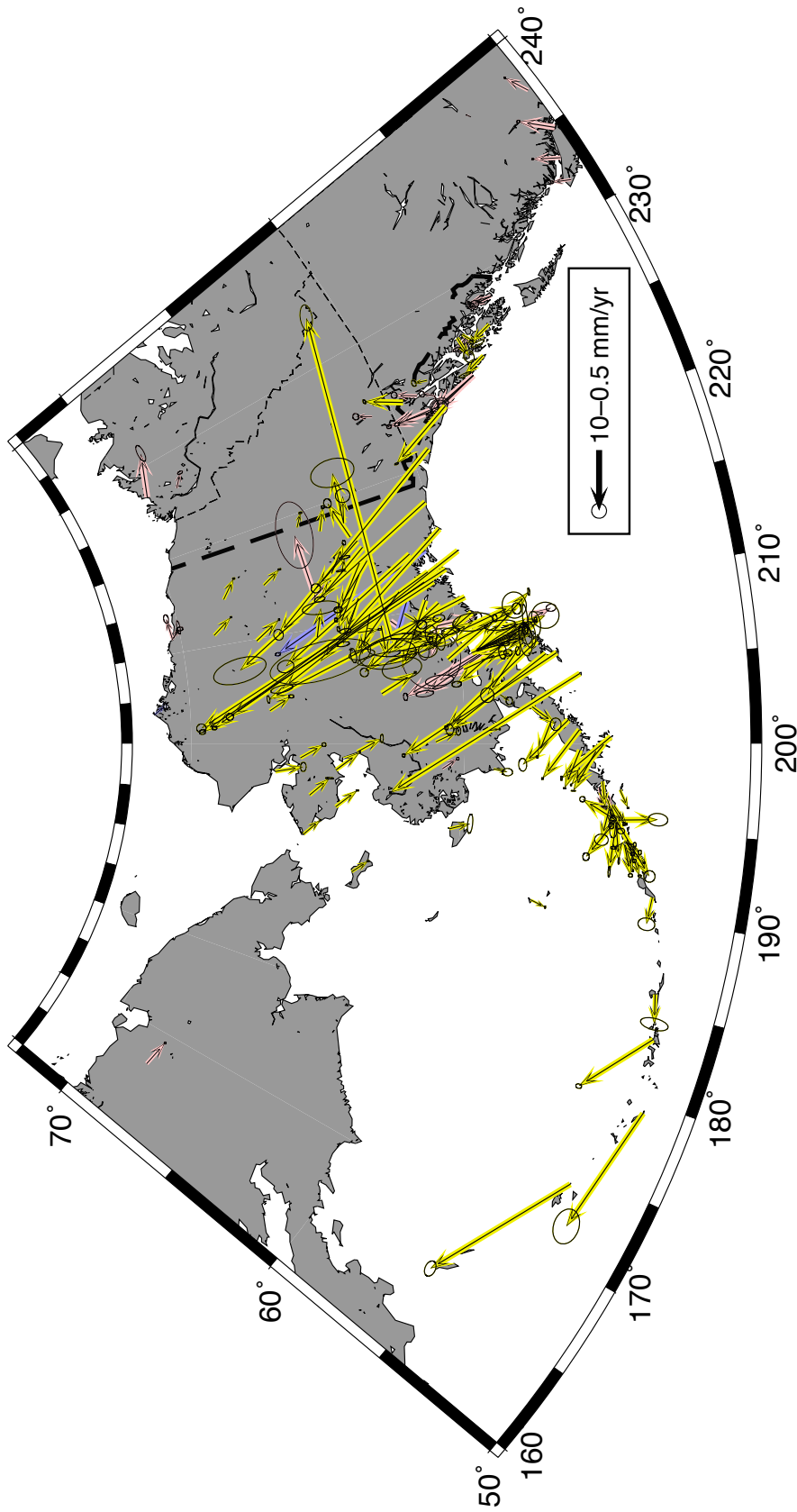


Figure 10: Same

as Figure 8 except for Alaska. Only velocities with horizontal standard deviations less than 5 mm/yr are shown

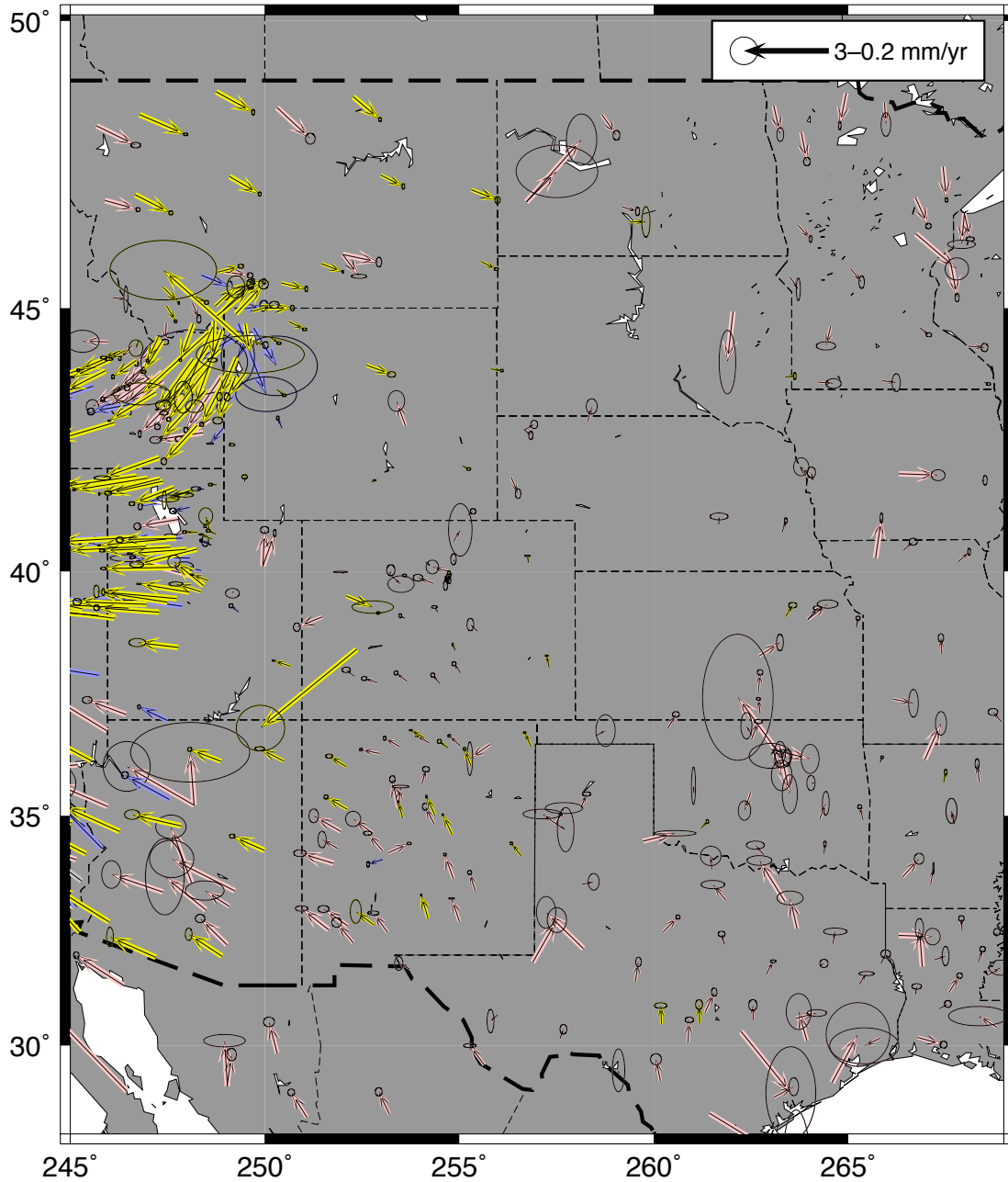


Figure 11: Same as Figure 8 except for Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown.

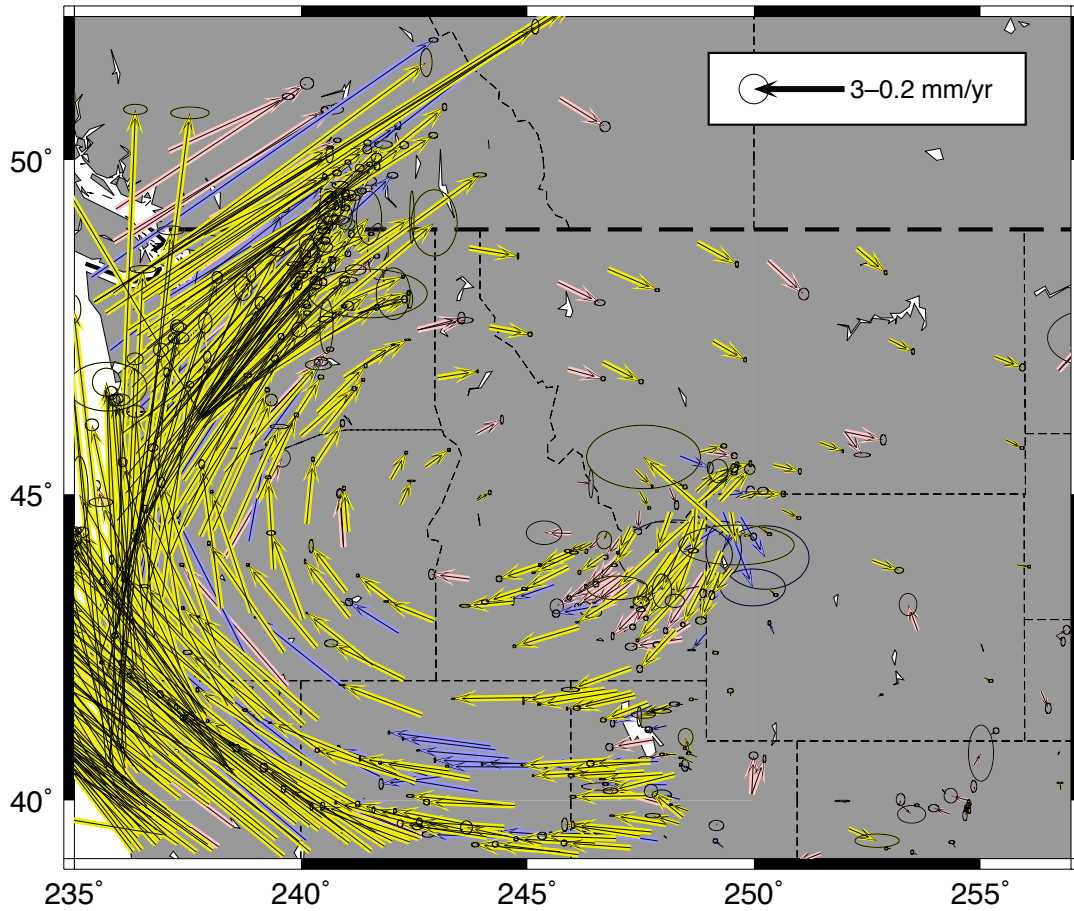


Figure 12: Same as Figure 8 except for Western Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown. Anomalous vectors at longitude 250° are in the Yellowstone National Park and most likely are showing volcanic processes.

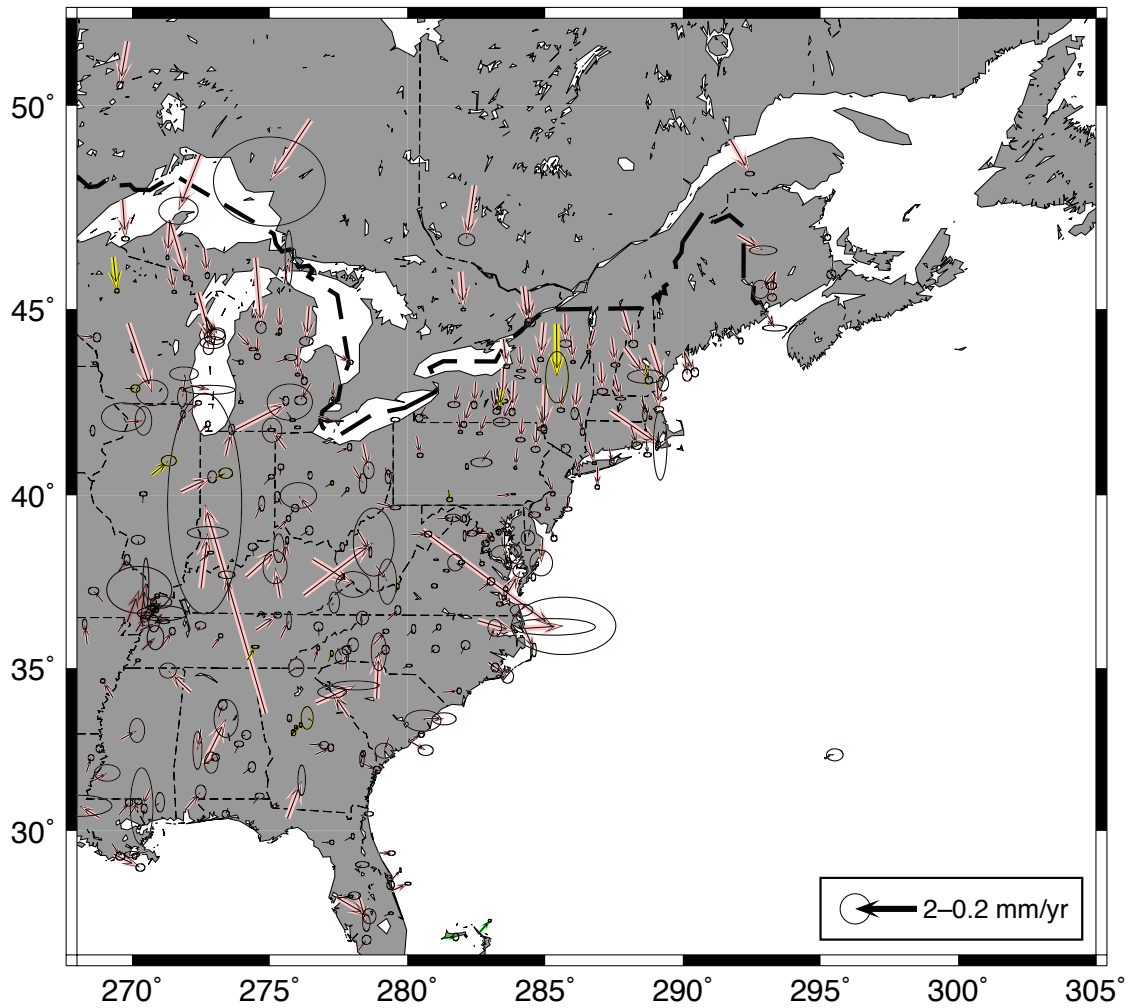


Figure 13: Same as Figure 8 except for the Eastern United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown. The systematic velocity of sites in the Northeast and central US show deviations for current GIA models in the horizontal velocities.

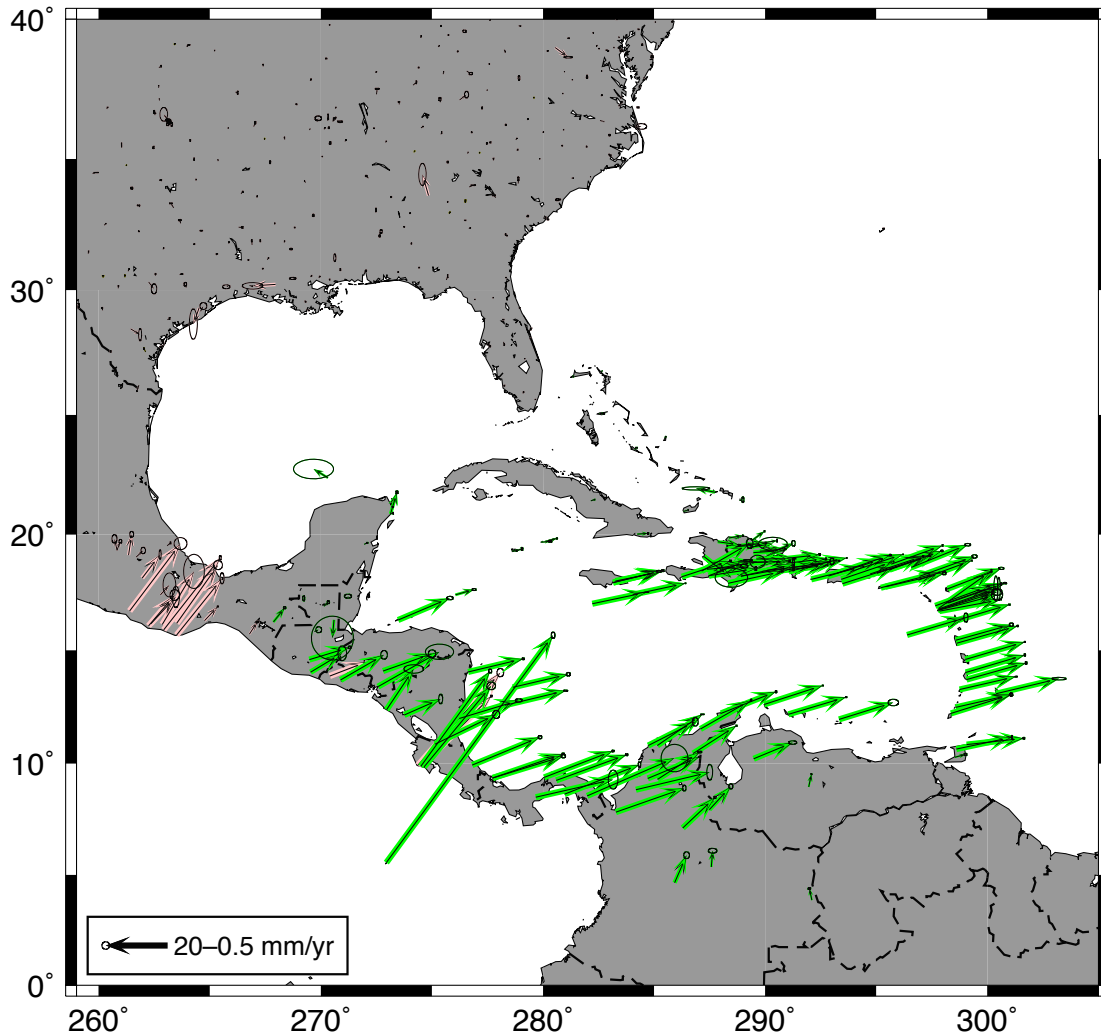


Figure 14: Same as Figure 8 except for the Caribbean region. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

Earthquake Analyses: 2019/09/15-2019/12/15

We use the NEIC catalog to search for earthquakes that could cause coseismic offsets at the sites analyzed by the GAGE analysis centers. Of the 26 earthquakes examined during this quarter, no earthquakes generated displacements more than 1 mm.

ANET Processing

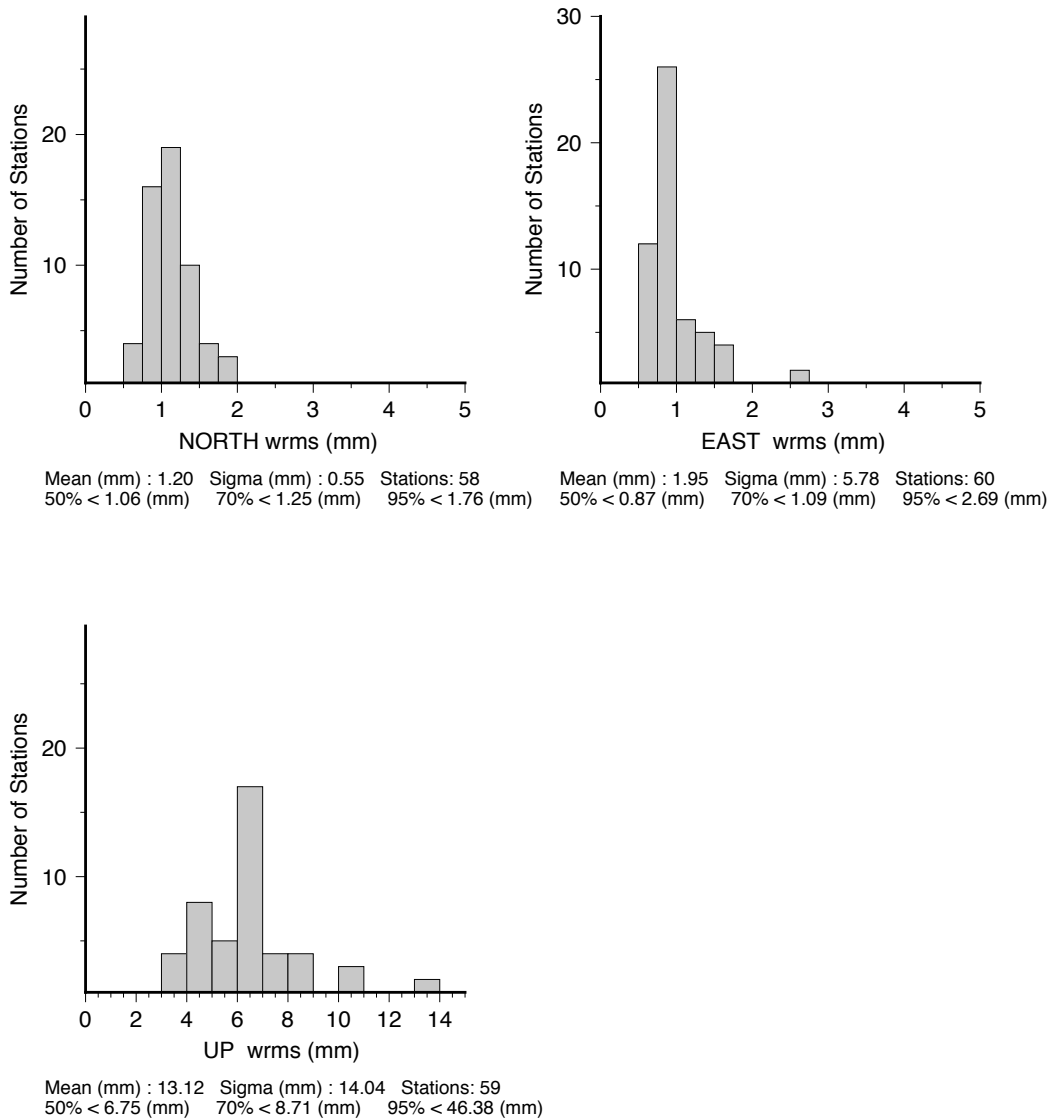
The ANET additional sites are being processed as a separate network and the frame resolved SINEX files will be given in the Antarctica 2014 reference frame (Altamimi *et al.*, 2016, 2017). We label this frame ant14. Time series and SINEX

files are generated only for final orbit solutions and are labeled as fanet (instead of final to avoid name conflicts with loose solutions). The IGS14 loose submission files are labeled with "lse14" to differentiate them from the IGS08 loose submissions which were simply labeled as loose. The statistics of the time series fits from the CWU solution for this quarter are given in Table 4.

Table 4: Statistics of the fits of 58 stations in the ANET region for CWU analyzed in the final orbit analysis between September 15, 2019 and December 21, 2019.

CWU	North (mm)	East (mm)	Up (mm)
Median (50%)	1.06	0.87	6.75
70%	1.25	1.09	8.71
95%	1.76	2.69	46.38

The histogram to the RMS scatter of the results for this quarter are shown in Figure A.1



Scatter-Wrms Histogram : FILE: CWU_ANT_Y2Q1.sum

Figure A.1: CWU solution histograms of the North, East and Up RMS scatters of the position residuals for 58 stations in Antarctica analyzed between September 15, 2019 and December 21, 2019. Linear trends and annual signals were estimated from the time series.

References

Altamimi, Z., P. Rebischung, L. Metivier, and X. Collilieux (2016), ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, *J. Geophys. Res. Solid Earth*, 121, 6109-6131, doi: 10.1002/2016JB013098.

Altamimi, Z., L. Metivier, P. Rebischung, H. Rouby, X. Collilieux; ITRF2014 plate motion model, *Geophysical Journal International*, Volume 209, Issue 3, 1 June 2017, Pages 1906-1912, <https://doi.org/10.1093/gji/ggx136>