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

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Period: 2018/10/01-2018/12/31

Table of Contents

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 2018/09/17 to 2019/01/26, time series velocity field analyses for the GAGE reprocessing analyses (1996-2019). Several earthquakes were investigated this quarter but only one generated coseismic displacements > 1mm. Even 47 ANSS(ComCat) ak20419010, Mw 7.0, 12km N of Anchorage (44.1 km depth) occurring at 2018/11/30 17:30 UTC. The largest displacement is at AC33 dN -37.22 ± 1.44, dE -6.06 ± 0.43, dU 79.57 ± 2.98 mm. The values are reported in the cwu.kalts_nam08.off file which reports all offsets estimated from the CWU solution.

Associated with report, event files, pbovel files and offset files have been queued to LDM with time tag 20190109215959.

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 GAGE analyses are in a transition between the ITRF2008 and ITRF2014 systems. Both NMT and CWU have submitted reprocessed IGS14 solutions with CWU solutions going back to 2002 when JPL IGS14 products start to be available and NMT going back to 1996 when IGS products are available. These solutions have all been processed and combined and we are waiting for release of the pre-2002 JPL products so that CWU solutions can be combined with the previously submitted NMT solutions..

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 2132 stations were processed which is 8 less than last quarter. In addition up to 63 sites are being processed in the ANET solutions.

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 17. 2018 – January 26, 2019.

For this report, we generated the statistics using the ~3 months of CWU results between September 17. 2018 and January 26, 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 2132 stations for CWU analyzed in the finals analysis between September 17. 2018 and January 26, 2019. Histograms of the RMS scatters are shown in Figure 1..

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
CWU	1.03	0.94	4.28
70%			
CWU	1.32	1.22	5.61
95%			
CWU	2.43	2.69	8.77

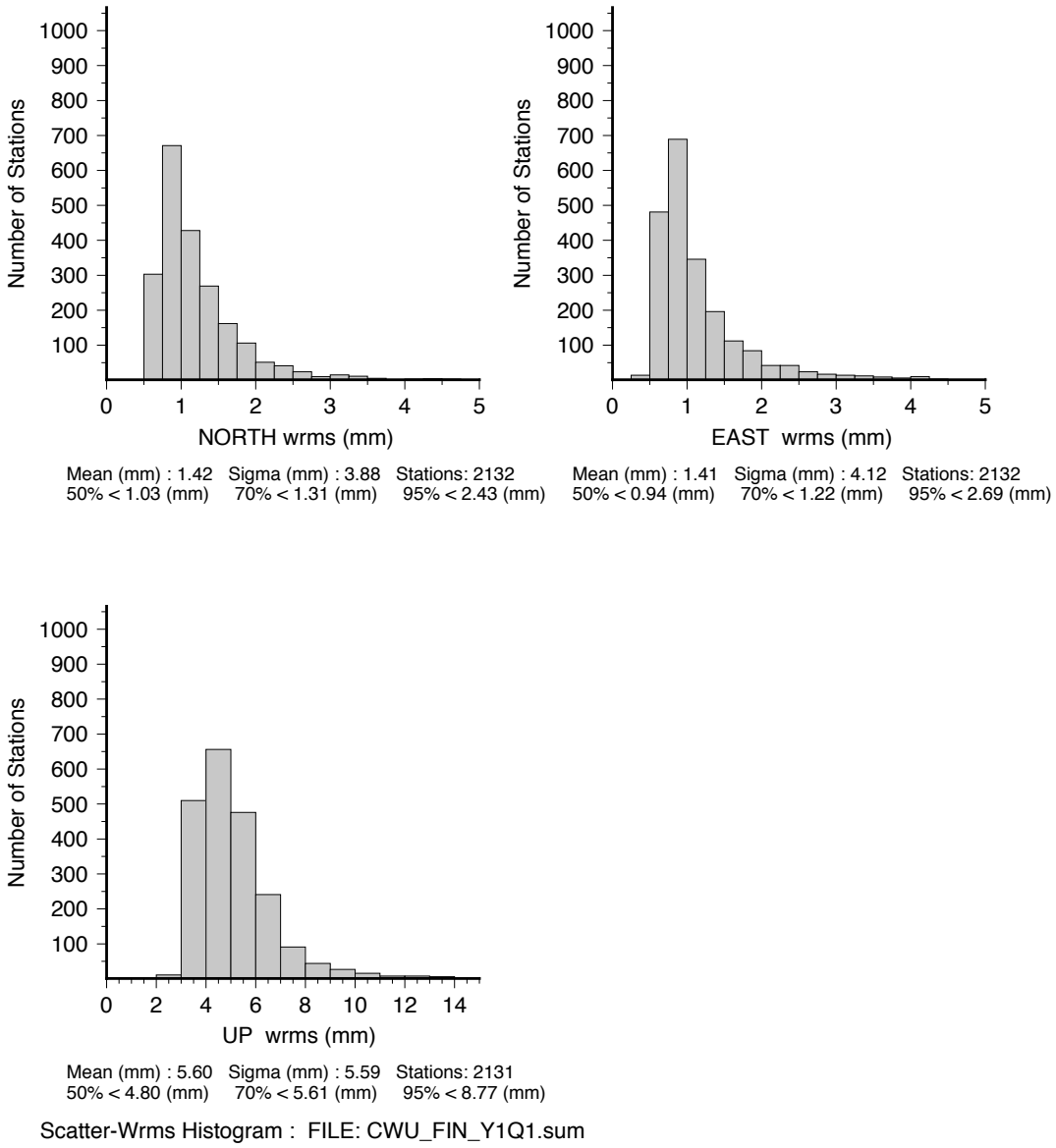

Figure 1: CWU solution histograms of the North, East and Up RMS scatters of the position residuals for 2132 stations analyzed between September 17. 2018 and January 26, 2019. Linear trends and annual signals were estimated from the time series.

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_Y1Q1.tab.

There are 2130 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_Y1Q1.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   106      1.3   0.65      1.4   0.68     7.1   0.76     15.76
 1NSU   106      0.9   0.52      1.0   0.60     5.9   0.79     15.02
 1ULM   106      0.8   0.44      0.9   0.57     6.2   0.83     15.62
 7ODM    83      2.4   0.36      4.1   0.42     8.4   0.49     17.77
…
 ZDV1   104      1.2   0.57      1.1   0.71     4.9   0.68     15.65
 ZKC1    98      0.9   0.45      0.7   0.44     5.1   0.70     15.65
 ZLA1   104      1.3   0.66      1.0   0.63     4.6   0.63     15.65
 ZLC1   104      1.0   0.49      0.9   0.54     4.8   0.67      1.03
 ZME1   104      1.3   0.65      0.9   0.56     5.9   0.78     15.88
 ZMP1   104      1.0   0.48      0.7   0.46     6.3   0.89     16.12
 ZNY1   104      1.1   0.55      1.0   0.59     5.7   0.77     16.03
 ZOA1   104      0.9   0.48      0.8   0.54     3.9   0.55      1.03
 ZSE1   104      1.3   0.60      1.1   0.67     4.9   0.69     16.03
 ZTL4   104      1.0   0.55      1.0   0.60     6.0   0.79     16.22
```

Table 2: RMS scatter of the position residuals for the CWU solution between September 17. 2018 and January 26, 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	0.91	0.85	4.21	889
NUCLEUS	0.90	0.79	4.17	205
GAMA	0.71	0.73	5.88	14
COCONet	1.40	1.49	6.74	79
USGS_SCIGN	1.77	2.08	6.02	114
Expanded	1.12	1.02	5.24	831
70%				
PBO	1.10	1.02	4.85	
NUCLEUS	1.07	0.91	4.66	
GAMA	0.81	0.80	6.20	
COCONet	1.76	1.81	7.76	
USGS_SCIGN	2.05	2.93	6.98	
Expanded	1.36	1.28	5.85	

95%			
PBO	2.09	1.93	7.47
NUCLEUS	1.73	1.63	7.87
GAMA	1.22	0.97	6.60
COCONet	3.48	4.12	13.56
USGS_SCIGN	3.20	5.18	12.66

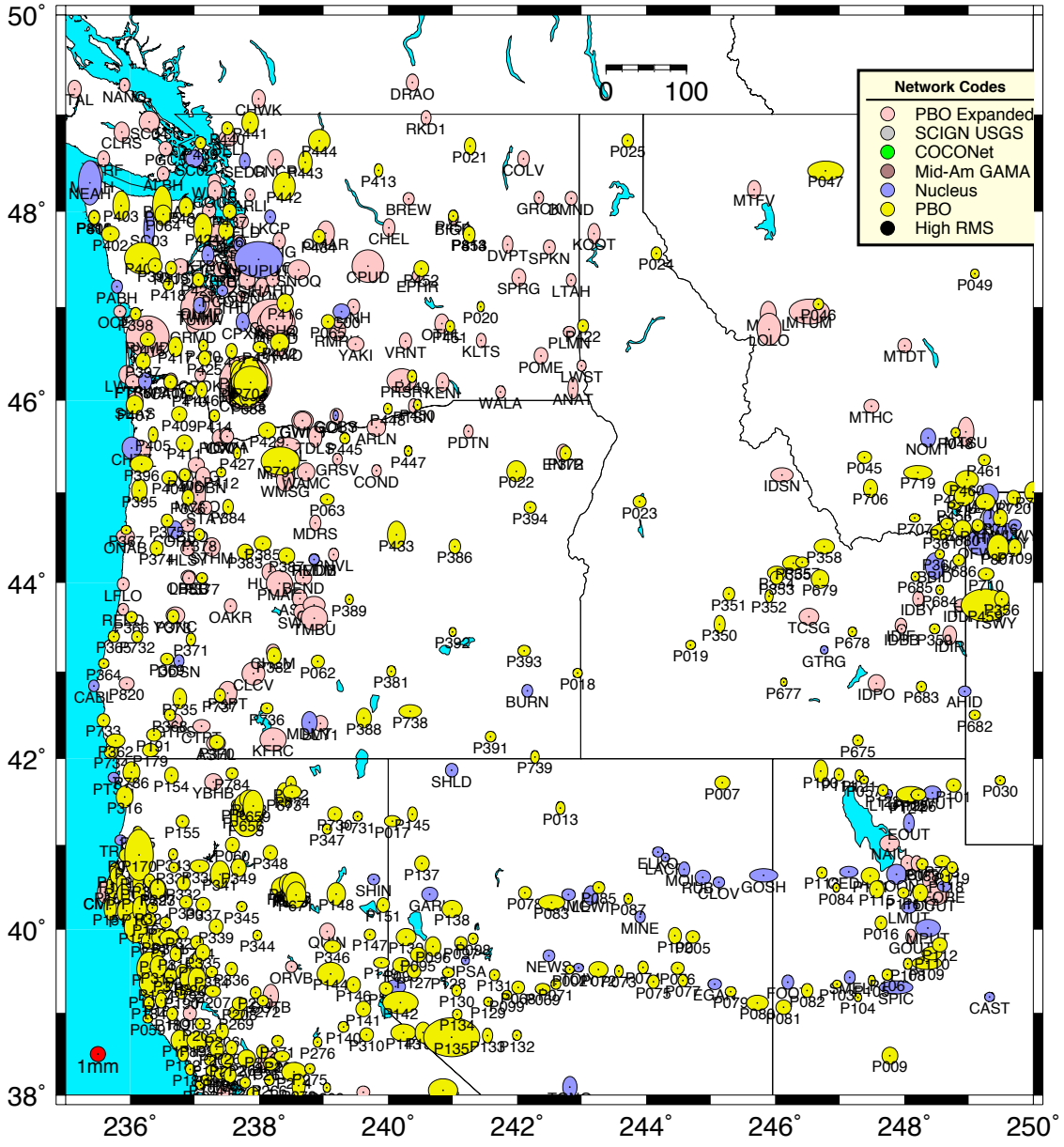

Figure 2: Distribution of the RMS scatters of horizontal position estimates from the CWU analysis for the Northern Western United States. The color of the ellipses that give the north and east RMS scatters denotes the network given by the legend in the figure. The small red circle shows the size of 1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

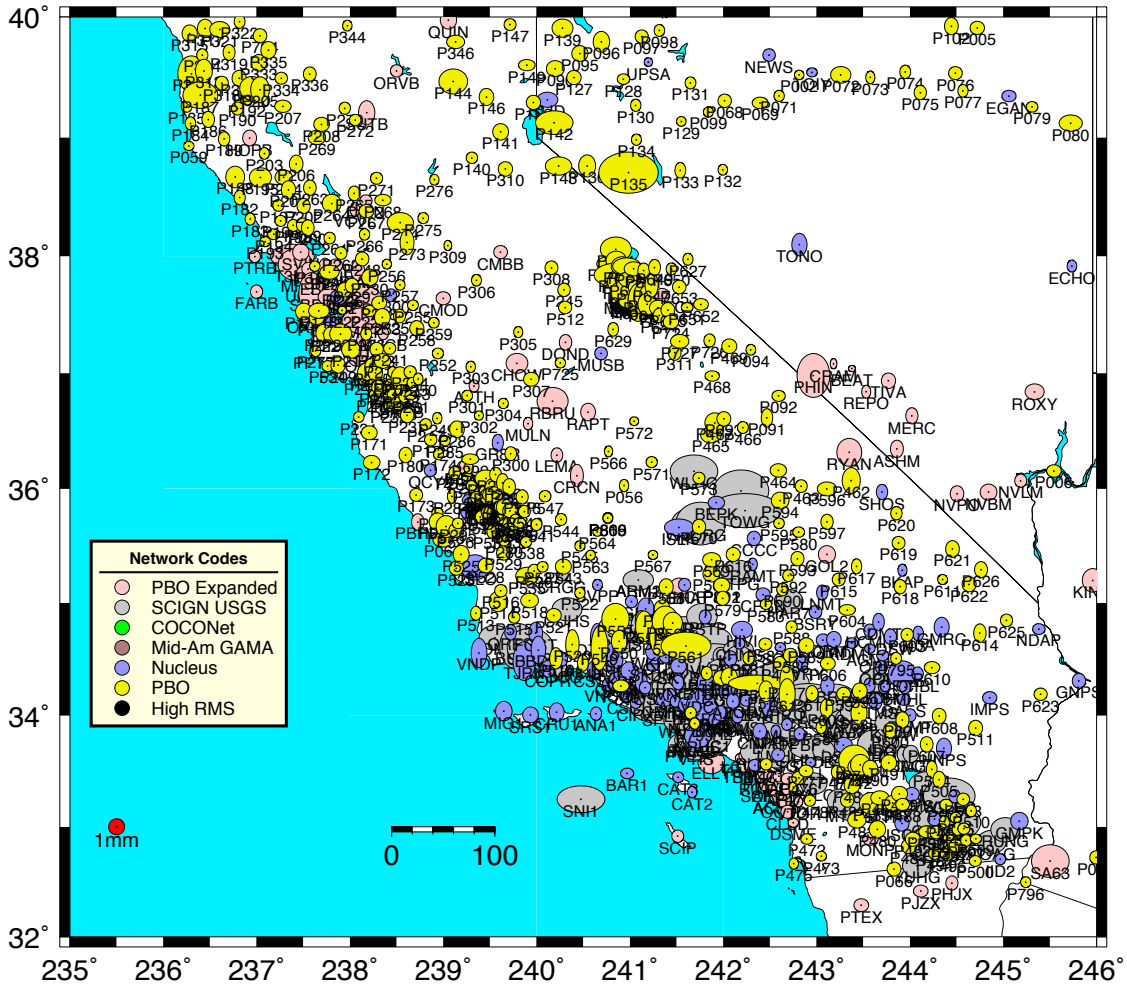

Figure 3: Same as Figure 4 except for the Southern Western United States. Black circles show large RMS scatter sites.

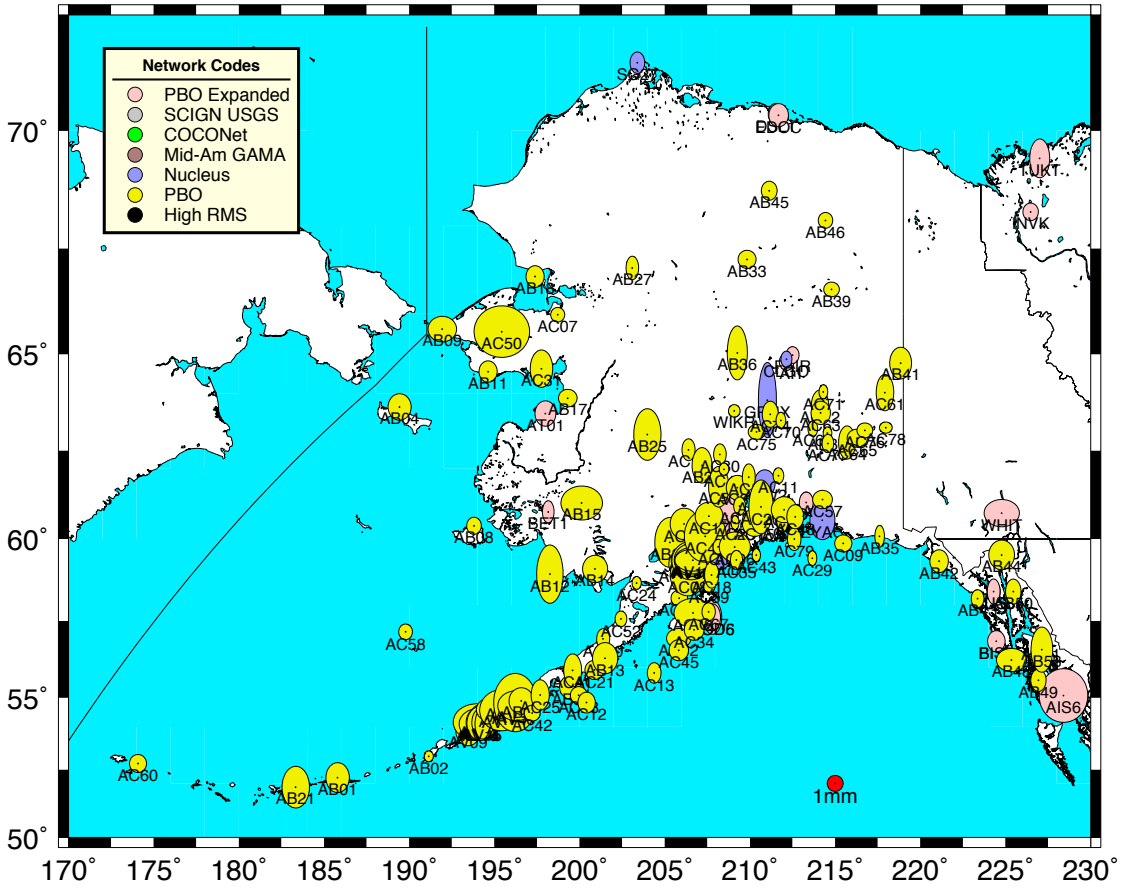

Figure 4: Same as Figure 4 except for the Alaskan region.

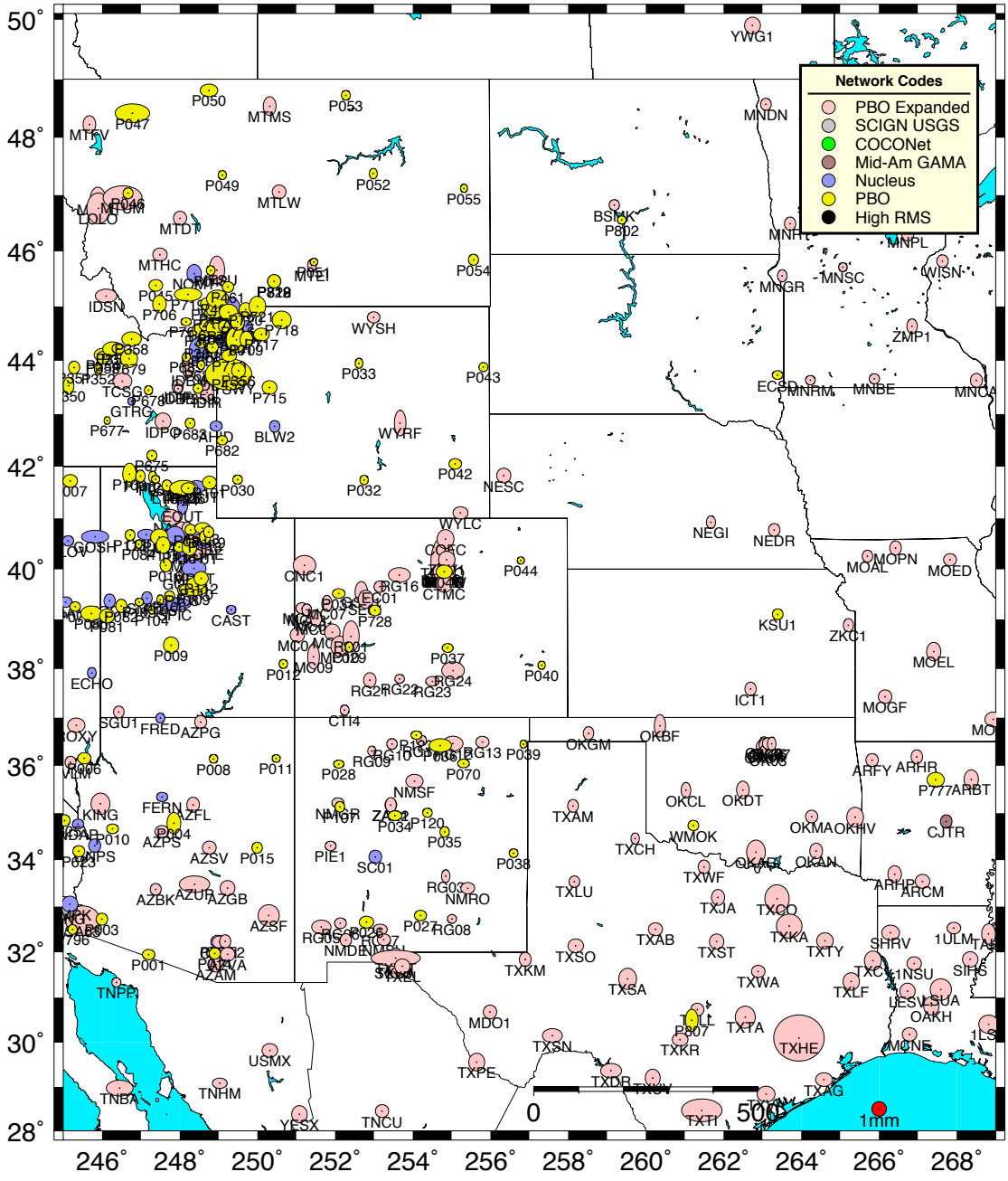

Figure 5: Same as Figure 4 except for the Central United States

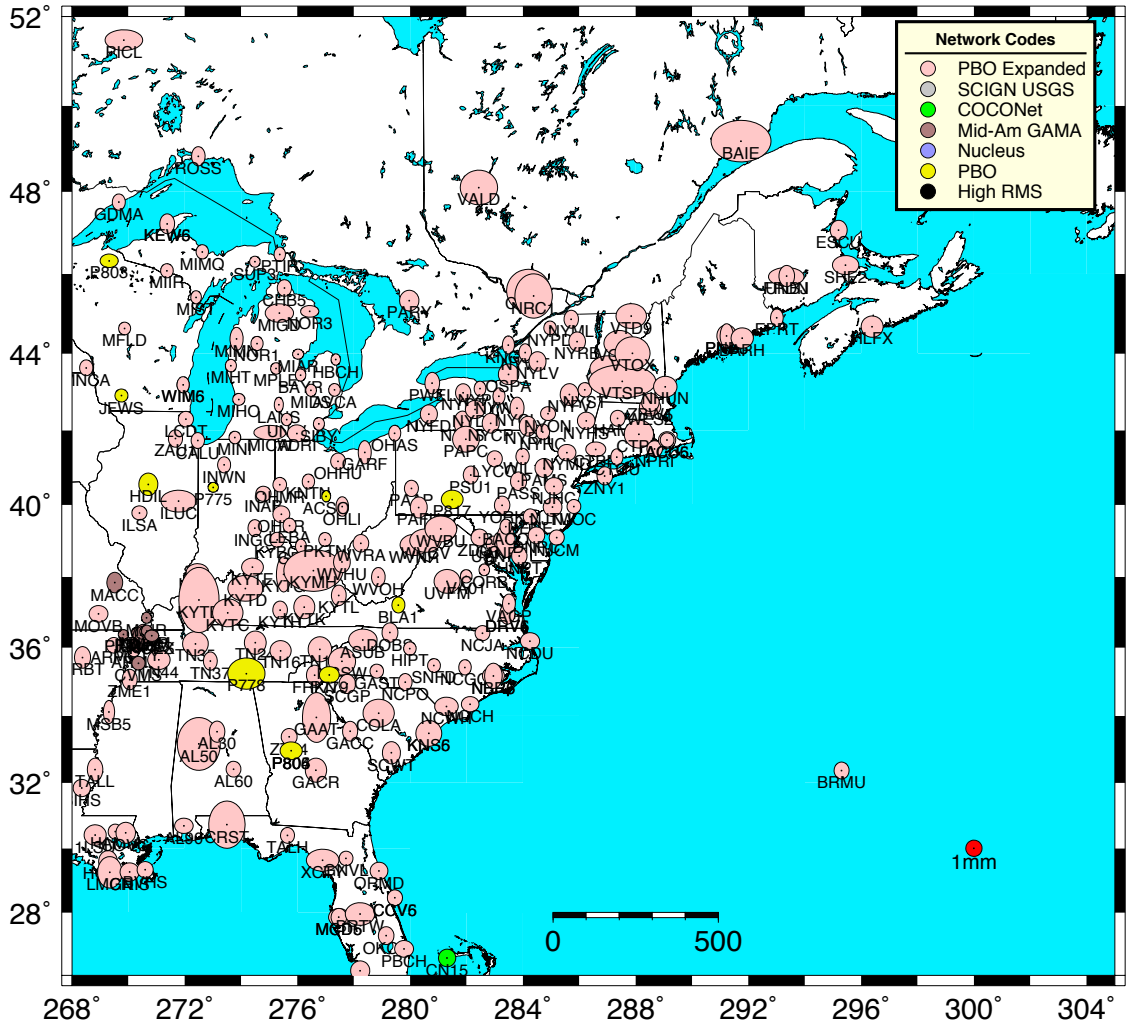

Figure 6: Same as Figure 4 except for the Eastern United States

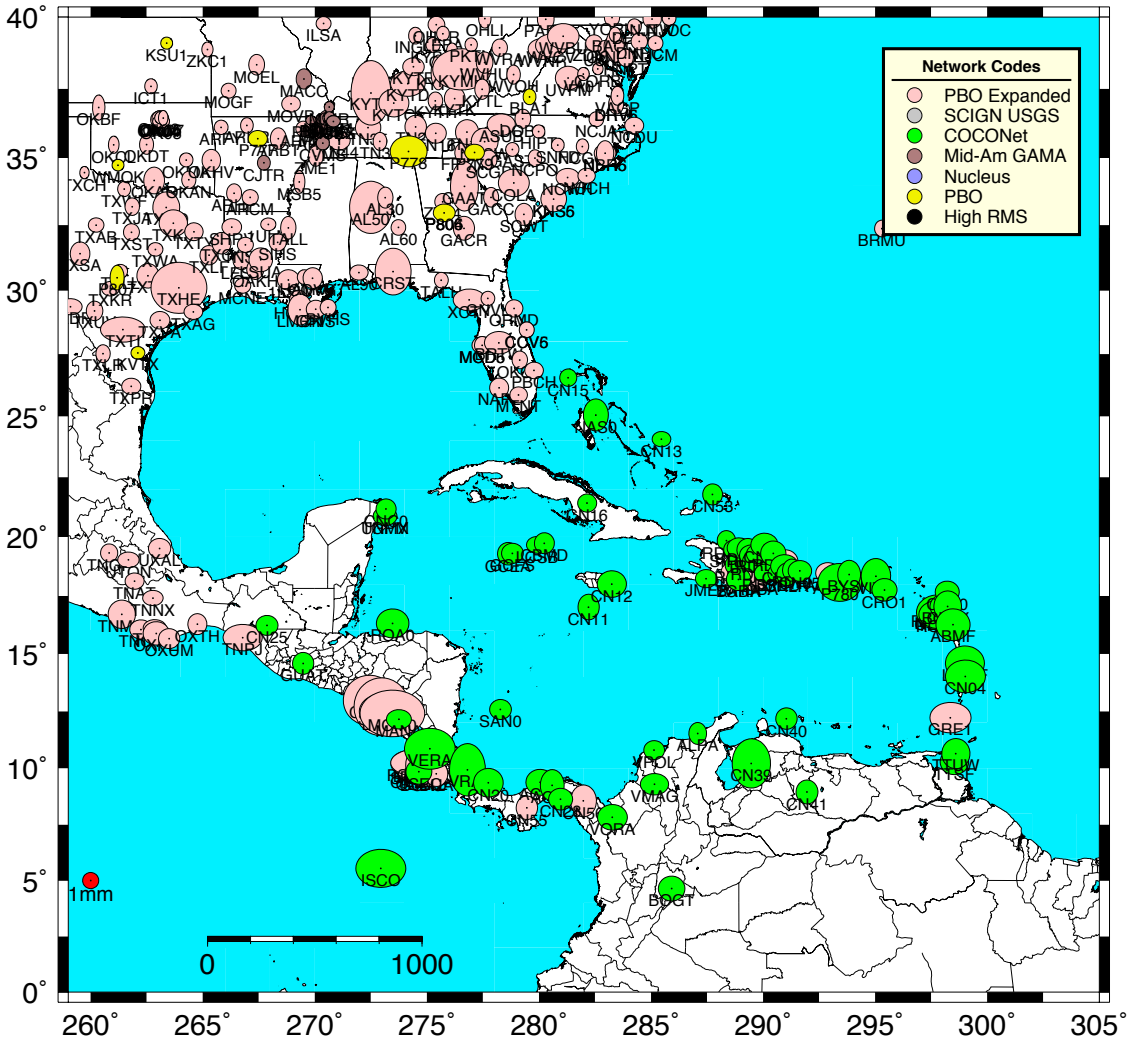

Figure 7: Same as Figure 4 except for the Caribbean region.

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. The current earthquake and discontinuity files used in the GAGE ACC analyses are 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.

Snapshot velocity field analysis from the reprocessed PBO analysis.

For this quarterly report, we generate velocity estimates for the reprocessed results and the current GAGE analyses that are in the NAM08 reference frame using the CWU analysis. There are 2545 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_nam08_180909.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_180909.snpvel.

Table 3: Statistics of the fits of 2545 stations analyzed CWU in the reprocessed analysis for data collected between Jan 1, 1996 and January 26, 2019.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
CWU	1.35	1.33	6.00
70%			
CWU	1.70	1.65	6.82
95%			
CWU	3.47	3.46	10.62

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.

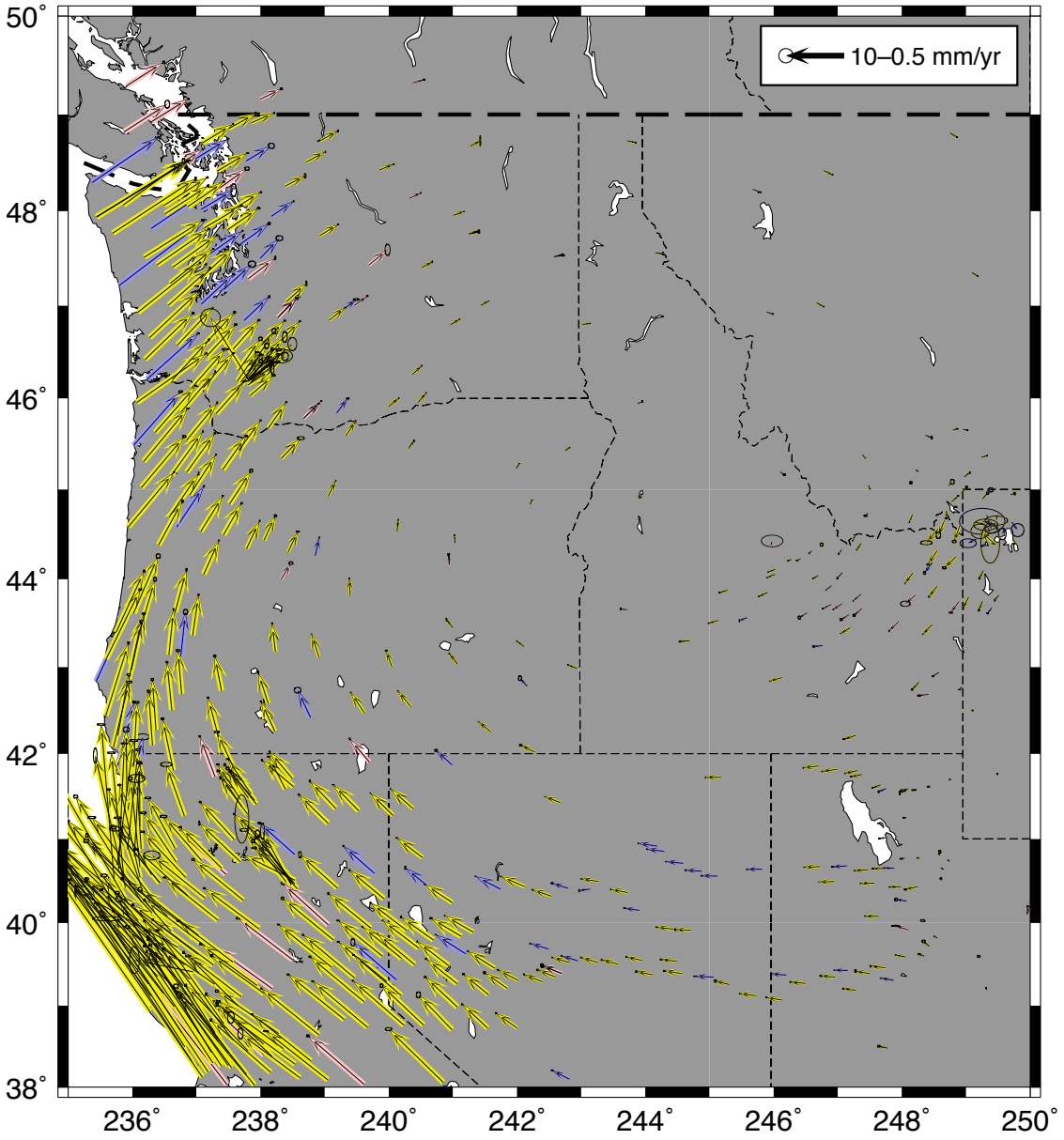

Figure 8: Velocity field estimates for the Pacific north-west from the CWU solution generated using time series analysis and the FOGMEX error model. 95% confidence interval error ellipses are shown. The color scheme of the vectors matches the network type legend in Figure 4. Only velocities with horizontal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

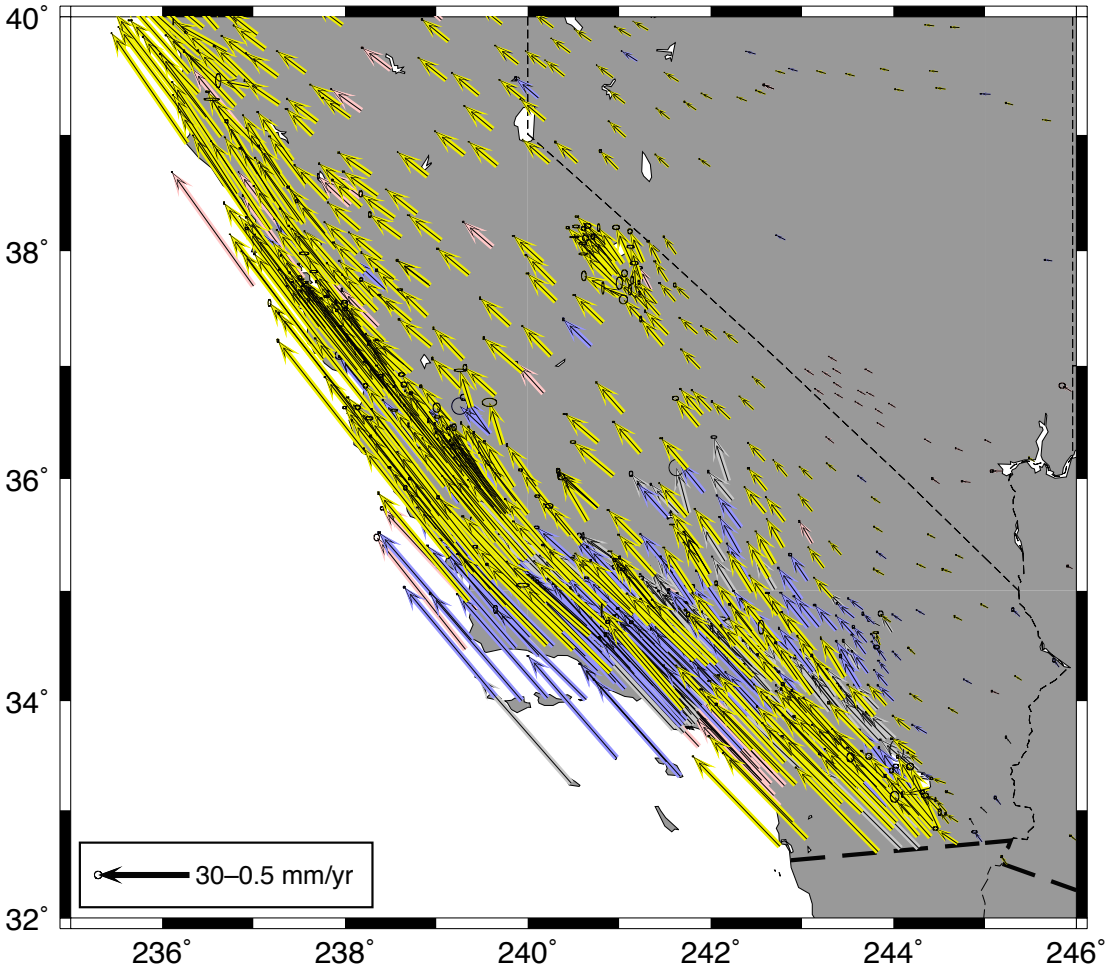

Figure 9: Same as Figure 10 except for South Western United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown.

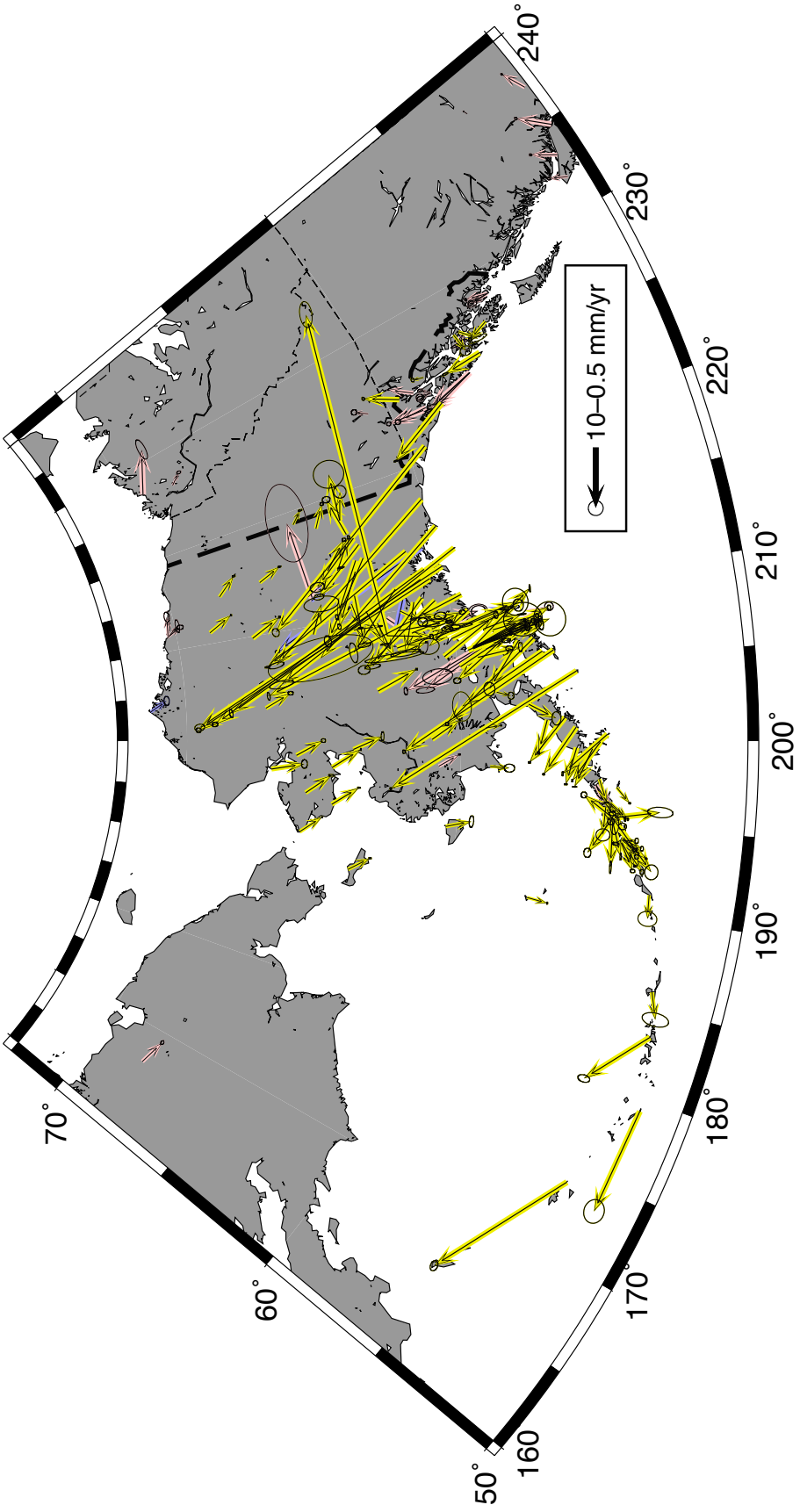
240°
230°
220°
210°
200°
190°
180°
170°
160°
70°
60°
50°
10–0.5 mm/yr

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

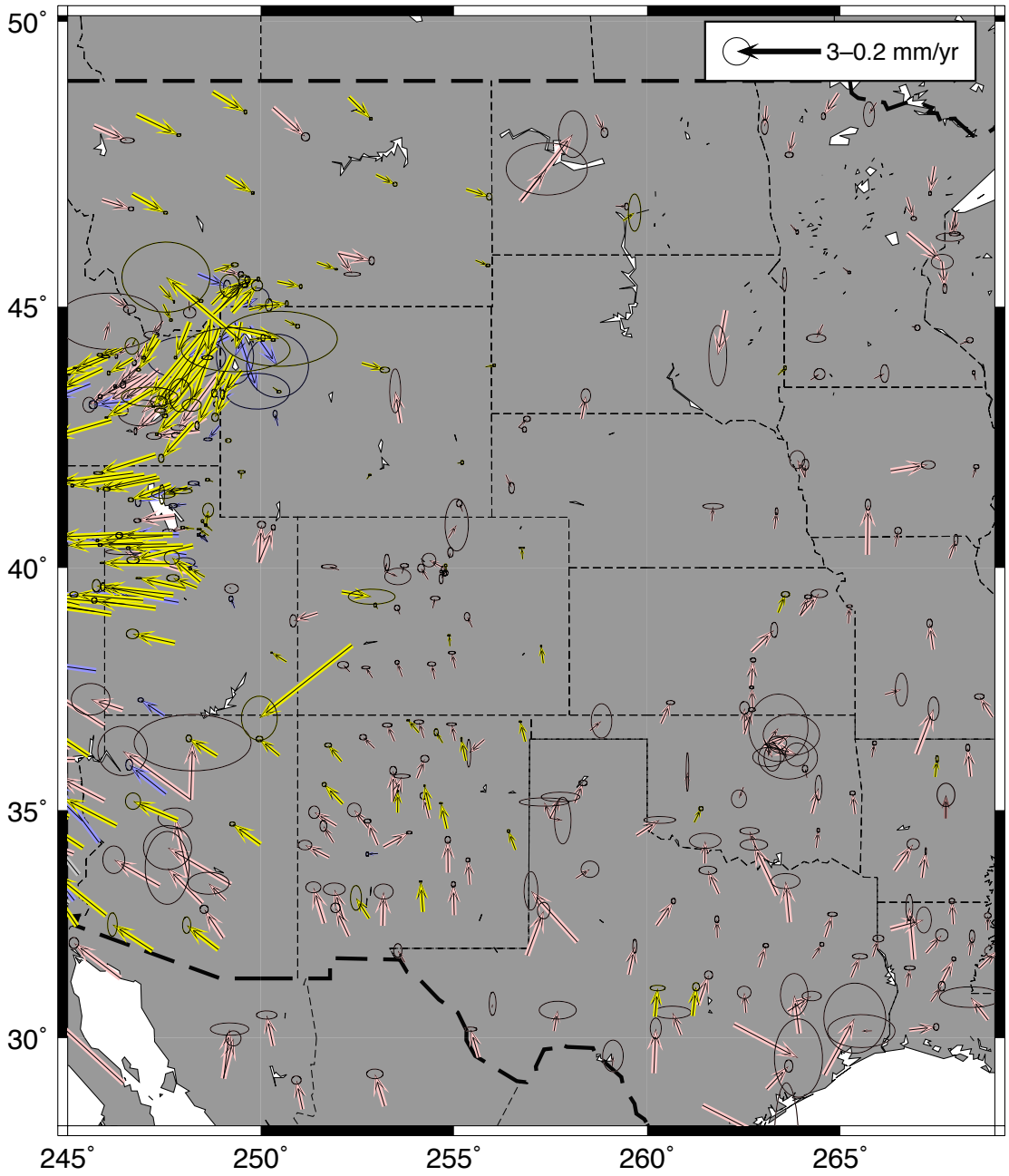

Figure 11: Same as Figure 10 except for Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown.

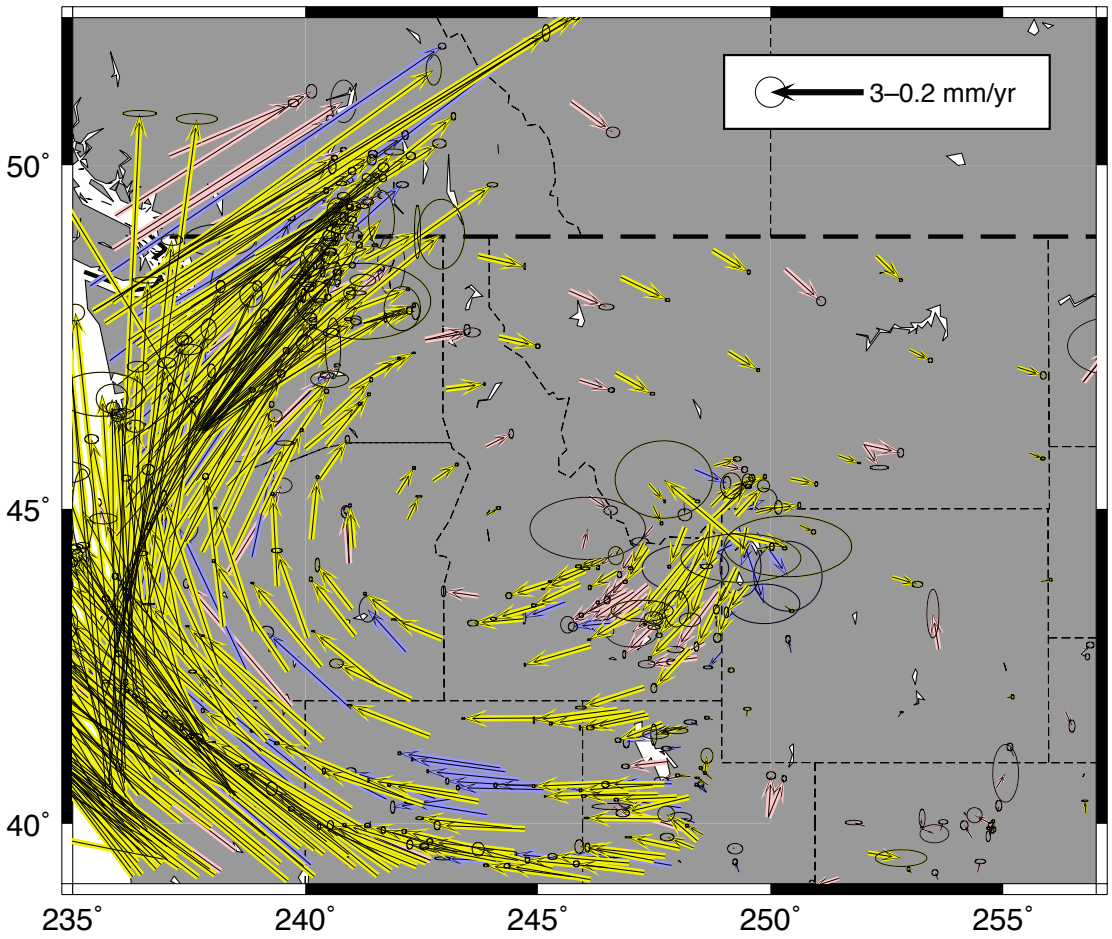

Figure 12: Same as Figure 10 except for Western Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown. Anomalous vectors at longitude 250° are in the Yellowstone National Park and most likely are showing volcanic processes.

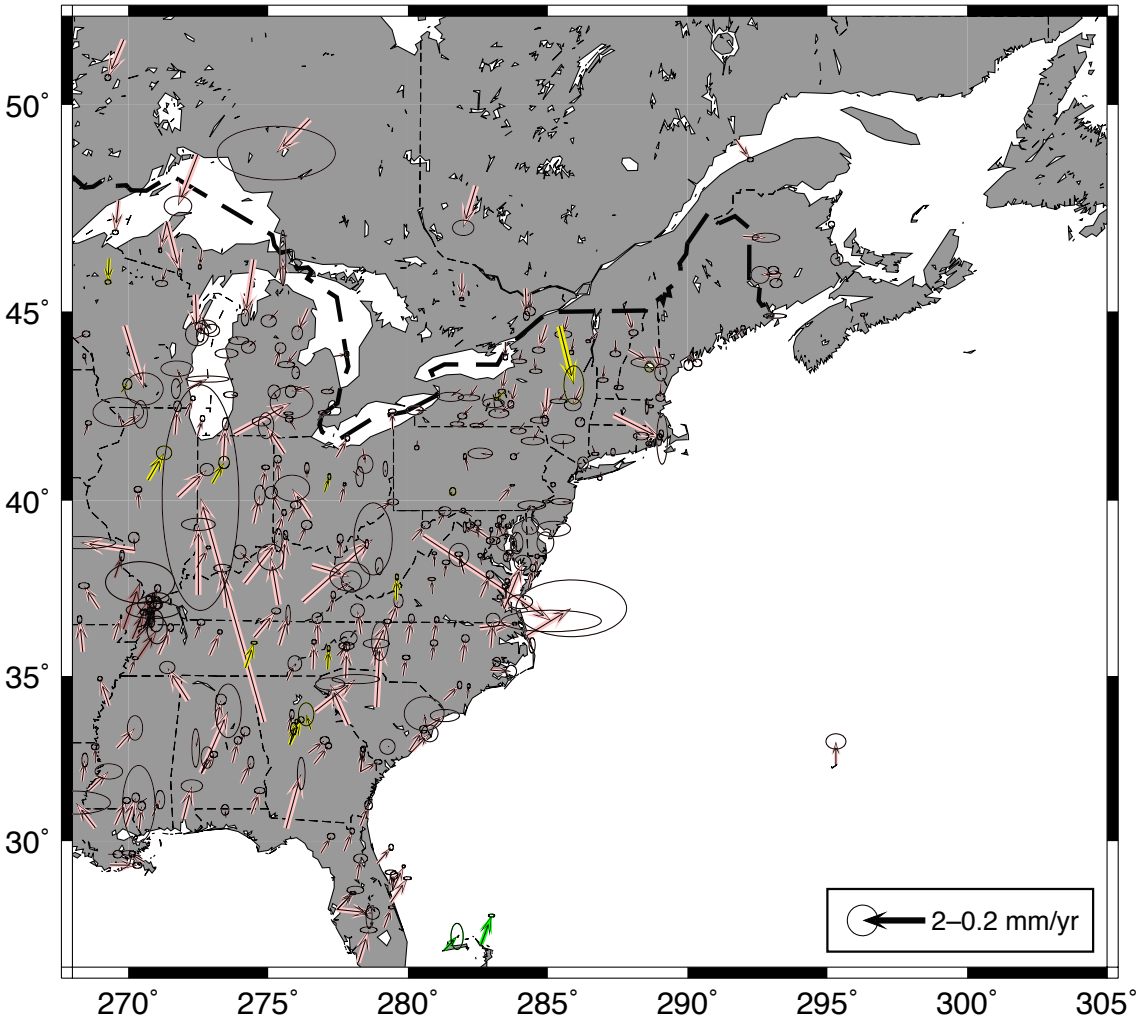

Figure 13: Same as Figure 10 except for the Eastern United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown. The systematic velocity of sites in the Northeast and central US show deviations for current GIA models in the horizontal velocities.

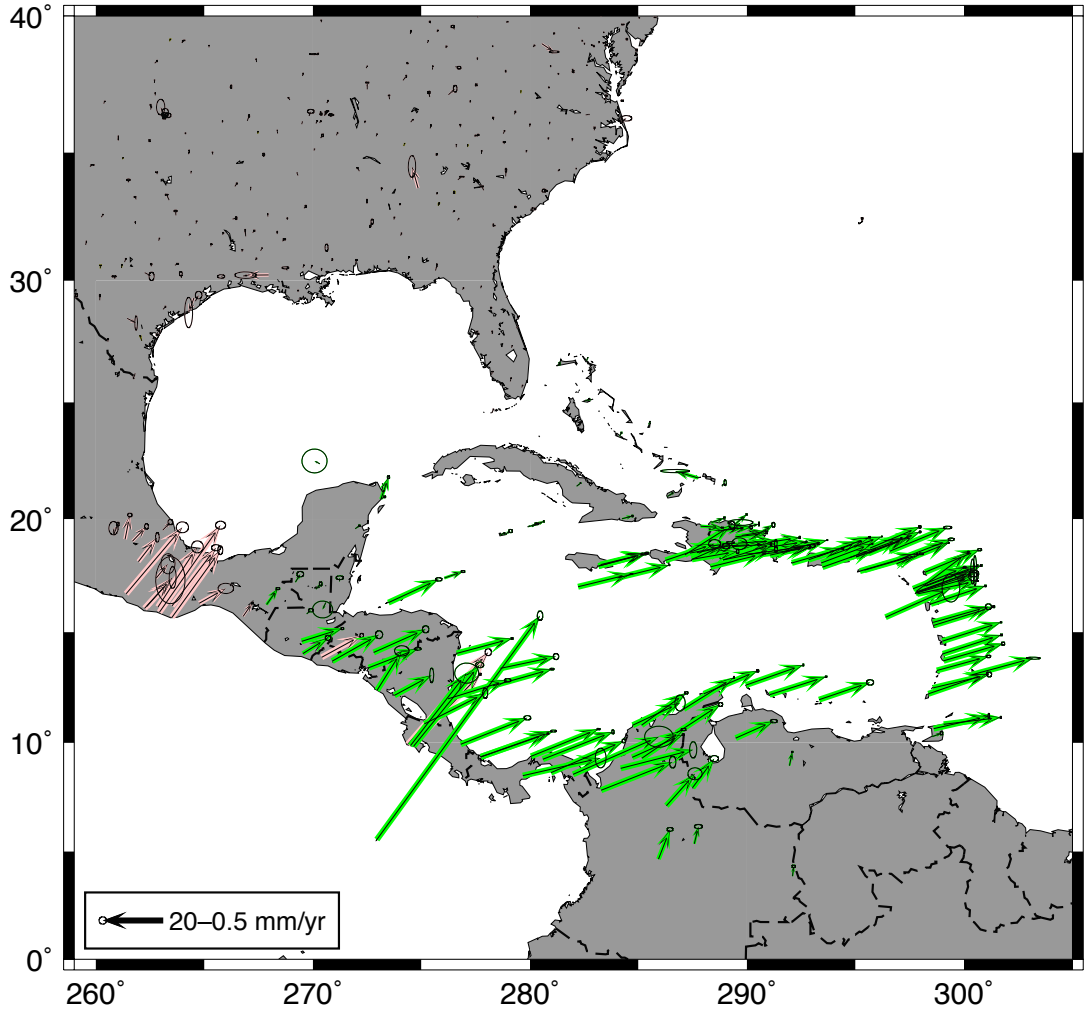

Figure 14: Same as Figure 10 except for the Caribbean region. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

Earthquake Analyses: 2018/09//15-2018/12/15.

We use the NEIC catalog to search for earthquakes that could cause coseismic offsets at the sites analyzed by the GAGE analysis centers. During this quarter only one new earthquake was detected. Even 47 ANSS(ComCat) ak20419010, Mw 7.0, 12km N of Anchorage (44.1 km depth) occurring at 2018/11/30 17:30 UTC. The largest displacement is at AC33 dN -37.22 ± 1.44, dE -6.06 ± 0.43, dU 79.57 ± 2.98 mm. The values are reported in the cwu.kalts_nam08.off file which reports all offsets estimated from the CWU solution.
All event files and plots have been queued to LDM with time-tag 20190109215959.

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 for the IGS08 loose submissions which were simply label as loose.

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