UNAVCO GAGE GNSS Data Product Notice to Users:
Notes on 2021 GAGE CWU NAM14 and ANT14 velocity fields
End GPS week 2136, 2020-12-19
2021-01-14

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These notes describe to development of the GAGE velocity fields using Central Washington University (CWU) analysis center results. These notes add supplemental information to:
"Notes on 2020 GAGE CWU NAM14 and ANT14 velocity fields End GPS week 2083, 2019-12-14"
https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GNSS_Velocity_Field_Release_Notes_20191214.pdf
"Notes on the 2019 GAGE NAM14 Combined Velocity field to GPS Week 2018 2019-09-15"
https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_Velocity_Field_20190612.pdf,
"Notes on the 2017 GAGE Velocity field to GPS Week 1977 2017-12-02";
https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GPS_Velocity_Release_Notes_20171202.pdf,
"Notes on the 2016 PBO Velocity field to Week 1925 2016-12-30",
https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GPS_Velocity_Release_Notes_20161230.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
Associated with this PDF is a folder DOI_201219 that contains the comparison velocity fields and other ancillary files used in generating the velocity fields. The contents of the folder are similar that associated with the Herring *et al.*, (2016) paper.

Two velocity fields are described here. One in the North America (NA) region expressed in a North America fixed frame and the other in the Antarctica (ANT) region in an Antarctica fixed frame. The 2021 NA GAGE full velocity solution includes GPS data from GPS week 0834 (Jan-01-1996) to week 2136 (Dec-19-2020) and contains all reprocessed and operational data from the Central Washington University (CWU) analysis center in the ITRF2014 system realization of the North America fixed reference frame. The 2020 ANT solution uses CWU solutions from GPS week 1304 (Feb-12-2005) to week 2136 (Dec-19-2020).

The two sets of velocity fields in the GAGE velocity file format have been queued to LDM as cwu.final_igs14.vel. 20210109155903, cwu.final_nam14.vel. 20210109155903 (NA) and cwu.fanet_ant14.vel. 20210109155903, cwu.fanet_igs14.vel. 20210109155903 (ANT)

The reference frames for this release are NAM14 and ANT14 based on the ITRF2014 system [*Altamimi et al.,* 2016] and the North America plate Euler pole in the ITRF2014 system [*Altamimi, et al.,* 2017].

The complete analysis of the full GAGE velocity field generated from CWU SINEX files (i.e., incorporating full variance covariance matrices and allowing re-alignment of the reference frame for the velocity field) is now released. The 2015 release documents the methods being used to generate these velocity fields using combinations of sub-networks. These methods remain unchanged except now they are based solely on CWU SINEX files. The ANT region has a small enough number stations to allow a simply direct generation of the velocity field.

The process noise models, in the form of random walk time-step variances or process noise (RWPN) are given in All_PBO.rw for the NA region and All_ANT.rw for the ANT region. These values are generated by analysis of the position residuals from fitting the time series for each station. Stations 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 stations. Twenty stations are excluded from NAM14 based on this criterion (AC09 AC30 AV05 BLKM BLOK CASA CRCN ELMA FCTF LEMA MIDB NTOE P056 P323 P656 P708 SMM1 SMM2 TILC WLHG). Most of these stations have a combination of large systematics and/or short durations of valid data. The final full combination for the NAM14 reference frame we also excluded sites with <3 yr data span and process noise values greater than 4 mm^2/yr. These limits were placed to keep the total number of elements in the Kalman filter state vector less than 40,000. The final number of NAM14 stations was 2360. For the ANT analysis, we restrict the full analysis stations to those RW process noise less than 10 mm^2/yr. The following stations are included in the times series analyses only: PECE, WWAY, TOMO. KHLR, UTWH and LTHW. We also impose a minimum random walk process noise (RWPN) of 0.05 mm^2/yr. 468 stations in the NA and 15 stations in the ANT analysis 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. [*Herring et al*., 2016; *Floyd and Herring*, 2019]. The tsfit solution also generates a list of station 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 station position estimates is given in All_PBO_edits.eq. These edits can by AC or for both ACs. The total GAGE time series contain 12385822 station-days. The outlier criteria remove 32018 (0.26%) of CWU station-days of solutions.

NA processing.

The NA processing divides the 2627 stations analyzed into 34 networks each with approximately 80 station locations. 2360 of these sites are included in the final combination With breaks included, there are 6391 parameter names needed to represents the breaks in the time series. (The final number of estimated parameters for each network depends on the number of breaks needed at each station). The networks need from 125 to 362 individual station names to accommodate the discontinuities, with a median number of stations of 187. There is an average of 2.7 breaks per station in the 25 years. There is no overlap between the stations in the first 33 networks. A 34th network is created to tie all the other 33 networks into a single solution. To form the stations in the 34th network, three stations for each network are chosen so as to minimize the trace of the covariance matrix of the estimates of rotation and translation using these stations. Weights assigned to each station in accord with the expected variance of the velocity estimate for the station (i.e., combination of the RWPN and duration of data at the station). If equal weights are given to each station, this algorithm is the same as choosing the three stations that cover the largest area. The details of the stations in each network are given in All_PBO_netsel.use. The analyses of the 34 networks can be run in parallel and takes a few hours to run. The combination of the 34 networks uses ~11 Gbytes of memory for the CWU combination, along the equating of velocities (with a constraint of ±0.01 mm/yr) at stations with discontinuities takes about three days of CPU time. 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 NAM14 frame using 1372 stations in our hierarchical list of reference frame stations; (2) A North America frame aligned to IGS14 rotated into the North America frame using the 85 stations original used in ITRF2014 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 for the NA analysis and current day (2020-12-19 GPS Week 2136 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. Tables 1 and 2 compare the WRMS and NRMS scatters of the differences between the velocity estimates obtained using different analysis methods and from previous PBO combined NAM14 and NAM08 velocity solutions released at earlier times. Table 1's caption explains the naming scheme used to describe the solutions. 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 quarterly GAGE SNAPSHOT fields. The GK analysis can be aligned to the current NAM14 frame (NA) or be realigned to the IGS14 frame (IG). In all analyses, the same process noise models, discontinuities and post-seismic non-linear models (based on time series analyses) are used. Two set of comparison are shown. The first

do not re-align the velocity fields in any way. The RMS values are based on the simple differences between the estimates. The second part of the tables shows results with rotation and translation rates between the reference frames estimated. The numbers of stations do not match between the analyses because the GK analyses exclude stations with large process noise values. Tables 3 and 4 show the same type of comparison when we restrict the stations to the best 772 stations in the solution. (These stations have velocity standards less than the median standard deviations in north, east and up in all three components, 0.14, 0.14 and 0.55 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, and in many cases smaller, suggesting that even the stations with the smallest sigma match in accordance with their sigmas.

Table 1: Comparison of North and East velocities between different velocity field determination methods for the NA analysis. No transformation parameters between the fields have been estimated. The codes for the solutions are: CCC_TTYY where CCC is the center 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 – NAM14, IG – IGS14 rotated to NA. The final entries CWU_2019, PBO_2018, PBO_2017, and PBO_2015 are the earlier 2019 CWU only solution (highlighted in yellow) and the 2018, 2017 and 2015 PBO full solutions The PBO fields before 2019 are in the NAM08 reference frame, # is the number of common stations 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
CWU_GKNA- CWU_TSLS	2352	-0.00	0.20	1.325	0.01	0.24	1.624
CWU_GKNA- CWU_TSKF	2352	-0.00	0.23	1.331	-0.00	0.28	1.609
CWU_GKNA- CWU_GKIG	2352	0.07	0.08	0.386	0.01	0.05	0.251
CWU_TSLS- CWU_TSKF	2625	0.00	0.13	1.074	-0.01	0.13	1.076
CWU_TSLS- CWU_GKIG	2352	0.07	0.22	1.363	-0.00	0.26	1.616
CWU_TSKF- CWU_GKNA	2352	0.00	0.23	1.331	0.00	0.28	1.609
CWU_GKNA- CWU_2019	2351	-0.02	0.13	0.660	0.03	0.14	0.722
CWU_GKNA- PBO_2018	2349	-0.02	0.21	1.065	0.03	0.22	1.103
CWU_GKNA- PBO_2017	2019	0.14	0.40	2.035	0.10	0.42	2.130
CWU_GKNA- PBO_2015	1964	0.09	0.41	1.999	0.09	0.43	2.116

Comparison with rotation and translation alignment

CWU_GKNA- CWU_TSLS	2352	-0.00	0.20	1.324	0.00	0.24	1.621
CWU_GKNA- CWU_TSKF	2352	-0.00	0.23	1.331	-0.00	0.28	1.608
CWU_GKNA- CWU_GKIG	2352	0.00	0.00	0.021	0.00	0.00	0.021
CWU_TSLS- CWU_TSKF	2625	-0.00	0.13	1.075	-0.00	0.13	1.071
CWU_TSLS- CWU_GKIG	2352	0.00	0.21	1.280	-0.00	0.26	1.598
CWU_TSKF- CWU_GKIG	2352	0.00	0.24	1.296	0.00	0.29	1.594
CWU_GKNA- CWU_2019	2351	0.00	0.13	0.642	0.00	0.14	0.702
CWU_GKNA- PBO_2018	2349	-0.00	0.21	1.075	0.00	0.21	1.080
CWU_GKNA- PBO_2017	2019	0.01	0.28	1.443	-0.00	0.35	1.808
CWU_GKNA- PBO_2015	1964	-0.00	0.31	1.490	-0.00	0.40	1.928

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

Soln1 - Soln2	#	HzMean (mm/yr)	HzWRMS (mm/yr)	HzNRMS	U Mean (mm/yr)	U WRMS (mm/yr)	U NRMS
CWU_GKNA- CWU_TSLS	2352	0.00	0.22	1.482	0.00	0.37	0.739
CWU_GKNA- CWU_TSKF	2352	-0.00	0.25	1.476	0.05	0.46	0.880
CWU_GKNA- CWU_GKIG	2352	0.04	0.07	0.325	0.23	0.26	0.405
CWU_TSLS- CWU_TSKF	2625	-0.00	0.13	1.075	0.03	0.41	1.148
CWU_TSLS- CWU_GKIG	2352	0.03	0.24	1.495	0.23	0.46	0.882
CWU_TSKF- CWU_GKNA	2352	0.00	0.25	1.476	-0.05	0.46	0.880
CWU_GKNA- CWU_2019	2351	0.00	0.14	0.692	0.04	0.37	0.573
CWU_GKNA- PBO_2018	2349	0.00	0.22	1.084	0.22	0.62	0.941
CWU_GKNA- PBO_2017	2019	0.12	0.41	2.083	0.71	0.94	1.578
CWU_GKNA- PBO_2015	1964	0.09	0.42	2.059	0.90	1.20	1.752
Comparison with rotation and translation alignment							
CWU_GKNA- CWU_TSLS	2352	-0.00	0.22	1.480	-0.01	0.37	0.741
CWU_GKNA- CWU_TSKF	2352	-0.00	0.25	1.476	0.02	0.46	0.872
CWU_GKNA- CWU_GKIG	2352	0.00	0.00	0.021	-0.00	0.00	0.008
CWU_TSLS- CWU_TSKF	2625	-0.00	0.13	1.073	0.02	0.40	1.138
CWU_TSLS- CWU_GKIG	2352	0.00	0.24	1.448	0.01	0.38	0.732
CWU_TSKF- CWU_GKIG	2352	0.00	0.27	1.453	-0.03	0.47	0.861
CWU_GKNA- CWU_2019	2351	0.00	0.13	0.673	0.00	0.37	0.568
CWU_GKNA- PBO_2018	2349	-0.00	0.21	1.078	0.08	0.58	0.884
CWU_GKNA- PBO_2017	2019	0.00	0.32	1.636	-0.04	0.55	0.926
CWU_GKNA- PBO_2015	1964	-0.00	0.35	1.723	0.11	0.74	1.083

Table 3: Comparison of North and East velocities similar to Table 1 except we limit the stations to those that have horizontal and vertical velocities sigmas both less than the median horizontal and vertical velocity sigmas. (Reason there are less than 1176 stations 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 0.14 and 0.14 mm/yr and the height velocity sigma less than 0.55 mm/yr.

Soln1 - Soln2	#	N mean (mm/yr)	N WRMS (mm/yr)	N NRMS	E mean (mm/yr)	E WRMS (mm/yr)	E NRMS
CWU_GKNA- CWU_TSLS	772	-0.00	0.07	0.635	-0.00	0.08	0.688
CWU_GKNA- CWU_TSKF	772	-0.00	0.08	0.606	-0.01	0.08	0.625
CWU_GKNA- CWU_GKIG	772	0.07	0.07	0.464	0.00	0.05	0.292
CWU_TSLS- CWU_TSKF	772	0.01	0.08	0.891	-0.01	0.07	0.867
CWU_TSLS- CWU_GKIG	772	0.07	0.10	0.825	0.00	0.09	0.721
CWU_TSKF- CWU_GKIG	772	0.07	0.11	0.769	0.01	0.10	0.692
CWU_GKNA- CWU_2019	772	-0.01	0.06	0.395	0.02	0.07	0.465
CWU_GKNA- PBO_2018	772	-0.02	0.10	0.640	0.01	0.12	0.753
CWU_GKNA- PBO_2017	671	0.16	0.30	1.979	0.03	0.20	1.333
CWU_GKNA- PBO_2015	671	0.14	0.31	1.897	0.02	0.20	1.207

Comparison with rotation and translation alignment

CWU_GKNA- CWU_TSLS	772	-0.00	0.07	0.634	0.00	0.08	0.686
CWU_GKNA- CWU_TSKF	772	-0.00	0.08	0.606	0.00	0.08	0.618
CWU_GKNA- CWU_GKIG	772	0.00	0.00	0.027	0.00	0.00	0.026
CWU_TSLS- CWU_TSKF	772	-0.00	0.08	0.888	-0.00	0.07	0.860
CWU_TSLS- CWU_GKIG	772	0.00	0.07	0.565	-0.00	0.08	0.622
CWU_TSKF- CWU_GKIG	772	0.00	0.08	0.566	-0.00	0.08	0.575
CWU_GKNA- CWU_2019	772	-0.00	0.06	0.361	0.00	0.07	0.450
CWU_GKNA- PBO_2018	772	-0.01	0.10	0.632	0.00	0.12	0.746
CWU_GKNA- PBO_2017	671	0.00	0.10	0.669	-0.00	0.11	0.733
CWU_GKNA- PBO_2015	671	-0.00	0.15	0.907	-0.00	0.14	0.845

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
CWU_GKNA- CWU_TSLS	772	-0.00	0.07	0.662	-0.00	0.24	0.659
CWU_GKNA- CWU_TSKF	772	-0.00	0.08	0.615	0.00	0.31	0.797
CWU_GKNA- CWU_GKIG	772	0.03	0.06	0.388	0.24	0.25	0.536
CWU_TSLS- CWU_TSKF	772	-0.00	0.08	0.879	-0.00	0.23	0.922
CWU_TSLS- CWU_GKIG	772	0.04	0.10	0.775	0.24	0.36	0.922
CWU_TSKF- CWU_GKIG	772	0.04	0.10	0.731	0.23	0.39	0.982
CWU_GKNA- CWU_2019	772	0.00	0.07	0.432	0.04	0.21	0.432
CWU_GKNA- PBO_2018	772	-0.01	0.11	0.699	0.18	0.40	0.818
CWU_GKNA- PBO_2017	671	0.09	0.26	1.687	0.67	0.78	1.788
CWU_GKNA- PBO_2015	671	0.08	0.26	1.590	0.83	0.98	1.854

Comparison with rotation and translation alignment

CWU_GKNA- CWU_TSLS	772	0.00	0.07	0.661	0.00	0.24	0.657
CWU_GKNA- CWU_TSKF	772	-0.00	0.08	0.612	0.02	0.31	0.797
CWU_GKNA- CWU_GKIG	772	0.00	0.00	0.026	-0.00	0.00	0.010
CWU_TSLS- CWU_TSKF	772	-0.00	0.08	0.874	0.01	0.23	0.918
CWU_TSLS- CWU_GKIG	772	-0.00	0.07	0.594	-0.01	0.25	0.640
CWU_TSKF- CWU_GKIG	772	0.00	0.08	0.570	-0.02	0.31	0.775
CWU_GKNA- CWU_2019	772	-0.00	0.06	0.408	0.02	0.20	0.425
CWU_GKNA- PBO_2018	772	-0.00	0.11	0.691	0.09	0.37	0.743
CWU_GKNA- PBO_2017	671	0.00	0.11	0.702	-0.02	0.34	0.789
CWU_GKNA- PBO_2015	671	-0.00	0.14	0.876	0.10	0.47	0.900

Over all the agreement between the different methods of estimating the velocities are very good with the WRMS difference in the NE components typically <0.3 mm/yr with the comparison to the PBO 2018, PBO 2017, and PBO 2015 velocity all being about 0.4 mm/yr. The comparison to last year's CWU only solution has WMRS scatters of 0.14 mm/yr. The height WRMS differences are less than 0.5 mm/yr with the comparisons to the earlier solutions being less than 1.2 mm/yr when no frame re-alignment is used and 0.75 mm/yr when the frames are re-aligned. The NRMS scatter of the differences is typically less than 1.1 for the different analysis methods and less than 2.1 when compared to earlier solutions.

As noted above, stations have been removed from the GLOBK Kalman filter estimation if the Horizonal Random Walk (HRW) value with >100 mm^2/yr. Velocity estimates for these stations only appear in the time series based analyses.

To show most of the distribution of the stations in the velocity field estimates, we show in Figure 1, the vertical rates of the 2343 stations which have vertical rates with standard deviations less than 5 mm/yr. Due to the process noise limits in the solution, only 9 stations have standard deviations in the vertical rates larger than this value.

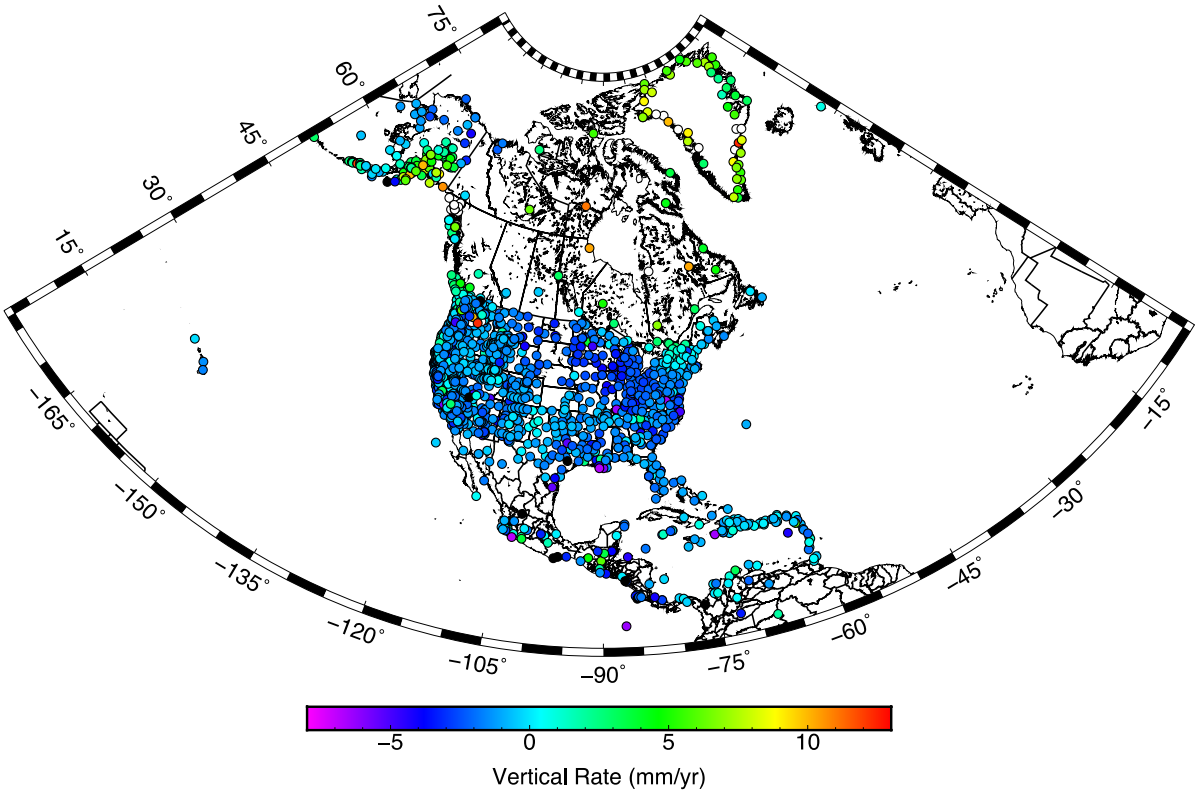

Figure 1: Vertical rate estimates for the 2343 stations in the CWU NAM14 solution with vertical velocity standard deviations of less than 5 mm/yr. (The whole solution contains 2352 stations).

ANT processing

The Antarctica processing is much simpler than the NA processing because of the much smaller number of stations and to a lesser degree the shorter duration of the data: GPS week 1304 (Feb-12-2005) to week 2136 (Dec-19-2020). In the time series analysis, 77 sites are included but in the GLOBK SINEX file combination of 71 stations are included. The 6 additional sites in the time series analysis have larger systematics that are likely to corrupt the combined analysis even with large process noise values assigned to the these stations. As with the NA analysis we compare the results of different analysis types (SINEX versus time series) and with the earlier 2018 combined PBO analysis results. The statistics of the comparison given in Tables 5-8 which are similar to Tables 1-4 for the NA analysis.

Table 5: Comparison of North and East velocities between different velocity field determination methods for the ANT analysis. No transformation parameters between the fields have been estimated. The codes for the solutions are: CCC_TTYY where CCC is the center 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 – NAM14, IG – IGS14 rotated to NA. CWU_2019 is last year's solution and is highlighted in yellow. The final entry PBO_2018 is the PBO full solution generated in June 2019. # is the number of common stations 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
CWU_GKAN- CWU_TSLS	71	0.01	0.15	1.005	0.00	0.13	0.897
CWU_GKAN- CWU_TSKF	71	-0.03	0.20	1.068	0.02	0.19	1.064
CWU_GKAN- CWU_GKIG	71	0.01	0.36	1.799	0.10	0.18	0.962
CWU_TSLS- CWU_TSKF	77	-0.04	0.17	1.151	0.02	0.16	1.156
CWU_TSLS- CWU_GKIG	71	-0.01	0.36	2.208	0.10	0.21	1.365
CWU_TSKF- CWU_GKIG	71	0.05	0.39	2.053	0.08	0.29	1.560
CWU_GKAN- CWU_2019	71	-0.02	0.12	0.595	0.03	0.13	0.674
CWU_GKAN- PBO_2018	60	-0.01	0.11	0.629	0.03	0.13	0.765
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	71	0.00	0.15	0.978	-0.00	0.13	0.890
CWU_GKAN- CWU_TSKF	71	-0.01	0.20	1.079	-0.01	0.17	0.964
CWU_GKAN- CWU_GKIG	71	-0.00	0.00	0.019	-0.00	0.00	0.020
CWU_TSLS- CWU_TSKF	77	-0.01	0.17	1.145	-0.01	0.14	1.031
CWU_TSLS- CWU_GKIG	71	0.00	0.16	0.984	0.00	0.14	0.875
CWU_TSKF- CWU_GKIG	71	0.01	0.20	1.070	0.01	0.17	0.948
CWU_GKAN- CWU_2019	71	0.02	0.10	0.512	0.00	0.11	0.559
CWU_GKAN- PBO_2018	60	0.03	0.12	0.661	-0.01	0.12	0.681

Table 6: Similar to Table 5 except here the mean horizontal velocity (HzMean, HzWRMS, HzNRMS) and vertical velocity (U columns) are compared.

Soln1 - Soln2	#	HzMean (mm/yr)	HzWRMS (mm/yr)	HzNRMS	U Mean (mm/yr)	U WRMS (mm/yr)	U NRMS
CWU_GKAN- CWU_TSLS	71	0.01	0.14	0.952	-0.04	0.44	0.854
CWU_GKAN- CWU_TSKF	71	-0.00	0.19	1.066	-0.06	0.60	1.088
CWU_GKAN- CWU_GKIG	71	0.06	0.28	1.442	-0.28	0.86	1.434
CWU_TSLS- CWU_TSKF	77	-0.01	0.16	1.154	-0.01	0.41	0.869
CWU_TSLS- CWU_GKIG	71	0.04	0.29	1.835	-0.26	0.89	1.707
CWU_TSKF- CWU_GKIG	71	0.07	0.34	1.823	-0.24	1.12	2.028
CWU_GKAN- CWU_2019	71	0.01	0.12	0.636	0.18	0.50	0.830
CWU_GKAN- PBO_2018	60	0.02	0.12	0.700	0.23	0.44	0.820
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	71	-0.00	0.14	0.935	0.01	0.44	0.848
CWU_GKAN- CWU_TSKF	71	-0.01	0.18	1.023	-0.01	0.58	1.053
CWU_GKAN- CWU_GKIG	71	-0.00	0.00	0.020	-0.00	0.01	0.008
CWU_TSLS- CWU_TSKF	77	-0.01	0.16	1.089	-0.02	0.37	0.791
CWU_TSLS- CWU_GKIG	71	0.00	0.15	0.931	-0.01	0.45	0.855
CWU_TSKF- CWU_GKIG	71	0.01	0.19	1.011	0.02	0.58	1.057
CWU_GKAN- CWU_2019	71	0.01	0.10	0.536	0.05	0.42	0.699
CWU_GKAN- PBO_2018	60	0.01	0.12	0.671	0.09	0.37	0.678

Table 7: Comparison of North and East velocities similar to Table 1 except we limit the stations to those that have horizontal and vertical velocities sigmas both less than the median horizontal and vertical velocity sigmas. (Reason there are less than 35 stations 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 0.17 mm/yr and the height velocity sigma less than 0.52 mm/yr.

Soln1 - Soln2	#	N mean (mm/yr)	N WRMS (mm/yr)	N NRMS	E mean (mm/yr)	E WRMS (mm/yr)	E NRMS
CWU_GKAN- CWU_TSLS	25	-0.00	0.08	0.708	-0.00	0.08	0.759
CWU_GKAN- CWU_TSKF	25	-0.05	0.10	0.805	-0.01	0.10	0.815
CWU_GKAN- CWU_GKIG	25	-0.11	0.27	1.912	0.12	0.21	1.524
CWU_TSLS- CWU_TSKF	25	-0.05	0.08	0.851	0.00	0.12	1.238
CWU_TSLS- CWU_GKIG	25	-0.12	0.27	2.355	0.12	0.19	1.751
CWU_TSKF- CWU_GKIG	25	-0.06	0.29	2.118	0.13	0.26	1.986
CWU_GKAN- CWU_2019	25	-0.02	0.08	0.564	0.02	0.06	0.473
CWU_GKAN- PBO_2018	25	-0.01	0.08	0.610	0.03	0.05	0.418

Comparison with rotation and translation alignment

CWU_GKAN- CWU_TSLS	25	-0.00	0.07	0.637	0.00	0.07	0.729
CWU_GKAN- CWU_TSKF	25	-0.02	0.09	0.697	-0.01	0.09	0.741
CWU_GKAN- CWU_GKIG	25	-0.00	0.00	0.025	-0.00	0.00	0.026
CWU_TSLS- CWU_TSKF	25	-0.01	0.07	0.688	-0.01	0.09	1.011
CWU_TSLS- CWU_GKIG	25	0.00	0.07	0.654	-0.00	0.08	0.720
CWU_TSKF- CWU_GKIG	25	0.02	0.09	0.687	0.01	0.09	0.715
CWU_GKAN- CWU_2019	25	0.01	0.05	0.387	0.01	0.04	0.307
CWU_GKAN- PBO_2018	25	0.01	0.08	0.605	0.00	0.04	0.321

Table 8: Same as Table 7 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
CWU_GKAN- CWU_TSLS	25	-0.00	0.08	0.734	0.00	0.20	0.541
CWU_GKAN- CWU_TSKF	25	-0.03	0.10	0.810	-0.06	0.40	1.014
CWU_GKAN- CWU_GKIG	25	0.01	0.24	1.729	-0.02	0.58	1.358
CWU_TSLS- CWU_TSKF	25	-0.02	0.10	1.062	-0.04	0.29	0.905
CWU_TSLS- CWU_GKIG	25	0.00	0.23	2.075	-0.05	0.58	1.551
CWU_TSKF- CWU_GKIG	25	0.04	0.27	2.053	0.01	0.80	2.023
CWU_GKAN- CWU_2019	25	0.00	0.07	0.520	0.22	0.26	0.614
CWU_GKAN- PBO_2018	25	0.01	0.07	0.523	0.22	0.40	0.981
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	25	-0.00	0.07	0.684	-0.00	0.20	0.539
CWU_GKAN- CWU_TSKF	25	-0.01	0.09	0.719	-0.08	0.38	0.963
CWU_GKAN- CWU_GKIG	25	-0.00	0.00	0.026	-0.00	0.01	0.014
CWU_TSLS- CWU_TSKF	25	-0.01	0.08	0.865	-0.07	0.27	0.827
CWU_TSLS- CWU_GKIG	25	-0.00	0.08	0.688	0.00	0.20	0.544
CWU_TSKF- CWU_GKIG	25	0.01	0.09	0.701	0.07	0.38	0.961
CWU_GKAN- CWU_2019	25	0.01	0.05	0.349	0.04	0.13	0.315
CWU_GKAN- PBO_2018	25	0.01	0.06	0.484	0.05	0.31	0.762

The agreement between the different analysis methods and earlier solutions is at the 0.2 mm/yr and 0.5 mm/yr levels in the horizontal and vertical components. The NRMS scatter of the sites with better than the median horizontal and vertical sigmas are similar to NRMS values of all stations suggesting the sigmas are scaled consistently. The Figures 2 and 3 we show the horizontal and vertical motions of the 71 sites included in the GLOBK SINEX analysis.

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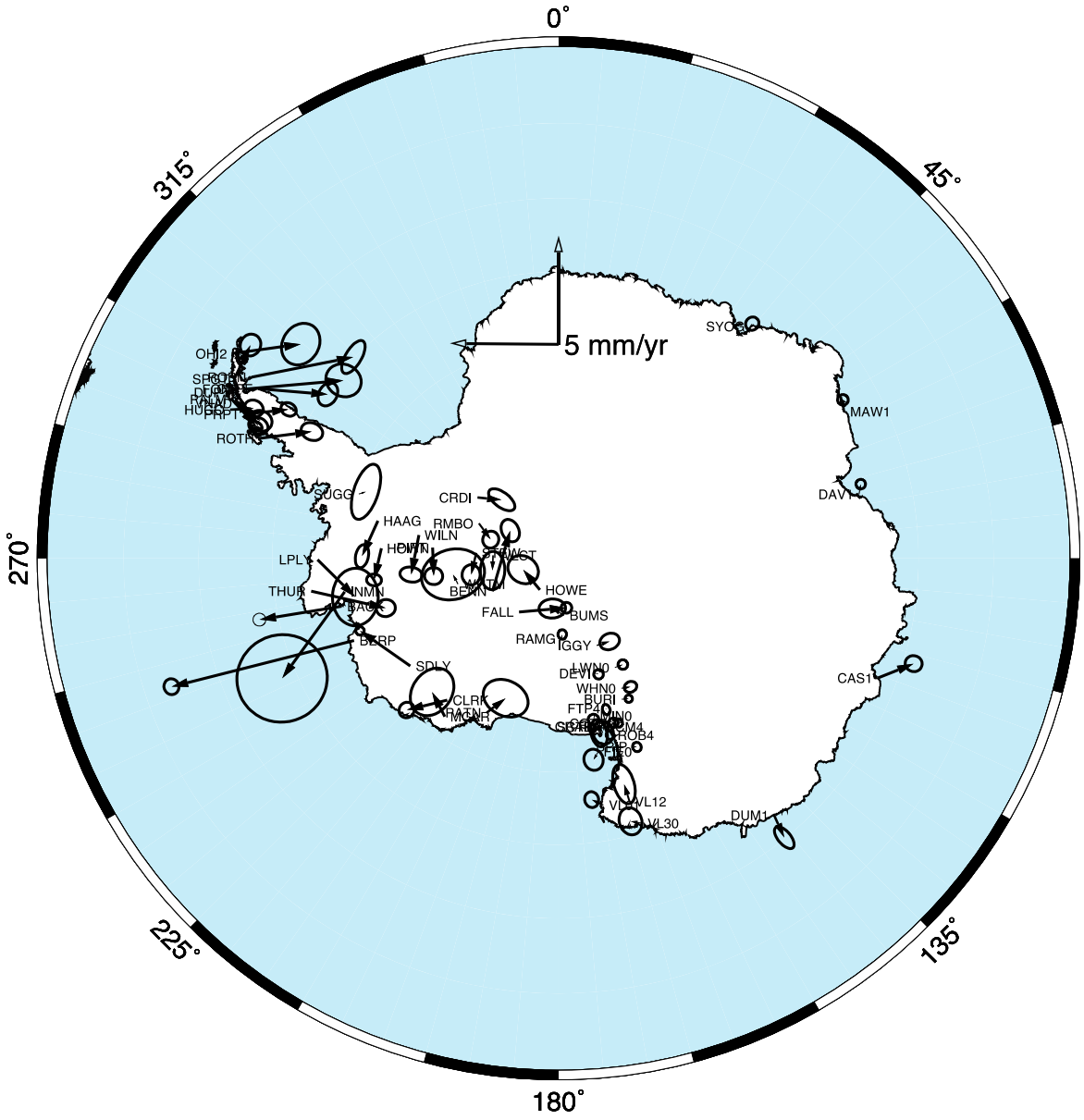

Figure 2: Horizontal motions in the ITRF2014 Antarctica fixed reference frame from the GLOBK SINEX file analysis (GKAN).

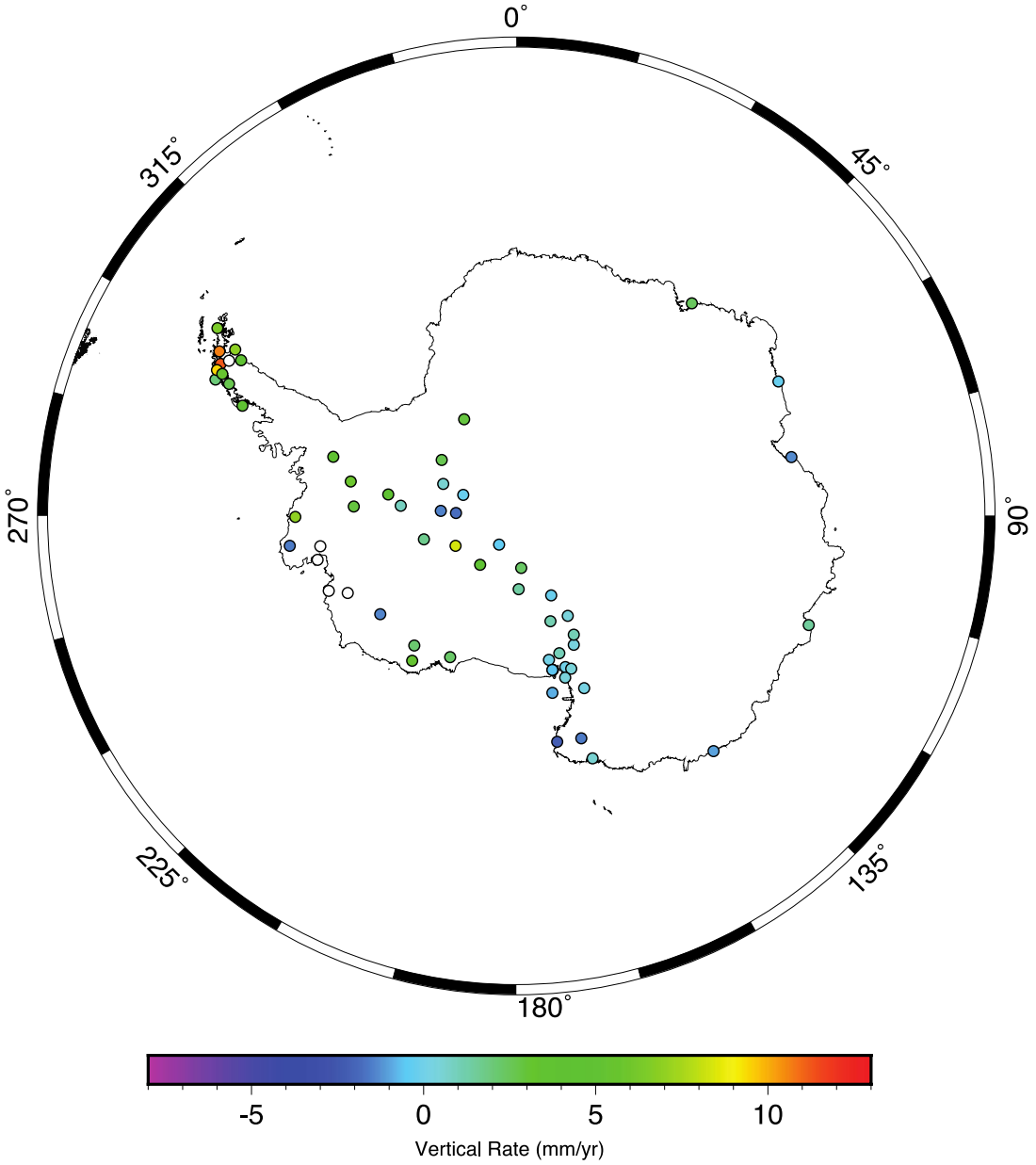

Figure 3: Vertical motions from the GLOBK SINEX file analysis (GKAN).