UNAVCO GAGE GNSS Data Product Notice to Users:
Notes on 2024 GAGE CWU NAM14 and ANT14 velocity fields
End GPS week 2294, 2023-12-30
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These notes describe the development of the GAGE velocity fields using Central Washington University (CWU) analysis center results. These notes add supplemental information to: "Notes on 2023 GAGE CWU NAM14 and ANT14 velocity fields End GPS week 2241, 2022-12-24" https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GNSS_Velocity_Field_Release_Notes_20221224.pdf and earlier velocity field release notes found at https://www.unavco.org/data/gps-gnss/derived-products/derived-products.html

Associated with this PDF is a folder rel_231220 that contains the comparison velocity fields and other ancillary files used in generating the velocity fields. The contents of the folder are similar to those associated with the Herring et al. (2016) paper.

Two velocity fields are described here. One in the North America (NA) region is expressed in a North America fixed frame, and the other is in the Antarctica (ANT) region in an Antarctica fixed frame. The 2023 NA GAGE full velocity solution includes GPS data from GPS week 0834 (Jan-01-1996) to week 2294 (Dec-30-2023) 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 2294 (Dec-30-2023).

The two sets of velocity fields in the GAGE velocity file format have been queued to LDM as cwu.final_igs14.vel. 20240122153743, cwu.final_nam14.vel. 20240122153743 (NA) and cwu.fanet_ant14.vel. 20240122153743, cwu.fanet_igs14.vel. 20240122153743 (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-aligning 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 of stations to allow a simple 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 with 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-six stations are excluded from NAM14 based on this criterion (AC09 AC30 AV05 BLKM BLOK CASA CBIA CRCN FCTF GV03 GV06 KRAC LEMA MIDB NTOE OLO7 P323 P656 P708 PNHG RHCG SEPR SMM1 SMM2 SMM4 WLHG). Most of these stations have a combination of large systematics and/or short durations of valid data. For 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 2194. 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: KHLR NLSN PECE TOMO and WWAY. We also impose a minimum random walk process noise (RWPN) of 0.05 mm^2/yr. 439 stations in the NA and 18 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. The outlier criteria remove 335633 (<0.30%) of CWU station-days of solutions.

NA processing.

The NA processing divides the 2687 (of a total of 2725) stations analyzed into 35 networks, each with approximately 80 station locations. The 2687 sites are included in the final combination with breaks included; there are 6495 parameter names needed to represent 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 386 individual station names to accommodate the discontinuities, with a median number of stations of 226. There is an average of 2.4 breaks per station in the 28 years. There is no overlap between the stations in the first 34 networks. A 36th network is created to tie all the other 34 networks into a single solution. To form the stations in the 35th network, three stations for each network are chosen to minimize the trace of the covariance matrix of the estimates of rotation and translation using these stations. Weights are assigned to each station following the expected variance of the velocity estimate for the station (i.e., a 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 35 networks can be run in parallel and takes a few hours to run. The combination of the 35 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 1679 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 68 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 the current day (2023-12-30 GPS Week 2294 for this analysis). The time series analyses for velocities are much faster, but the daily solutions need to be aligned with 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 earlier. 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 sets of comparisons are shown. The first set does 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 792 stations in the solution. (These stations have velocity standards less than the median standard deviations in north, east, and up in all three components, 0.13, 0.13, and 0.46 mm/yr, respectively). The number of stations is less than half the number of stations because the standard deviation condition must be met in all components). The NRMS values are very consistent with those in Tables 1 and 2 and, in many cases, smaller, suggesting that even the stations with the smallest sigma match consistent 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_2022-19, PBO_2018 are the earlier solutions (2022 is highlighted in yellow). 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	2194	0.00	0.15	1.138	0.00	0.21	1.597
CWU_GKNA- CWU_TSKF	2194	0.01	0.18	1.197	0.00	0.24	1.601
CWU_GKNA- CWU_GKIG	2194	-0.05	0.07	0.407	0.04	0.08	0.487
CWU_TSLS- CWU_TSKF	2726	0.00	0.13	1.121	-0.00	0.13	1.114
CWU_TSLS- CWU_GKIG	2194	-0.06	0.17	1.221	0.04	0.23	1.684
CWU_TSKF- CWU_GKIG	2194	-0.06	0.20	1.265	0.04	0.26	1.676
CWU_GKNA- CWU_2022	2164	-0.00	0.07	0.413	-0.00	0.07	0.408
CWU_GKNA- CWU_2021	2146	0.01	0.10	0.553	-0.01	0.10	0.557
CWU_GKNA- CWU_2020	2149	-0.03	0.12	0.668	0.00	0.13	0.722
CWU_GKNA- CWU_2019	2163	-0.05	0.16	0.884	0.03	0.16	0.874
CWU_GKNA- PBO_2018	2159	-0.05	0.21	1.141	0.03	0.22	1.203

Comparison with rotation and translation alignment

CWU_GKNA- CWU_TSLS	2194	0.00	0.15	1.139	-0.00	0.21	1.595
CWU_GKNA- CWU_TSKF	2194	-0.00	0.18	1.197	-0.00	0.24	1.599
CWU_GKNA- CWU_GKIG	2194	0.00	0.00	0.023	0.00	0.00	0.024
CWU_TSLS- CWU_TSKF	2726	-0.00	0.13	1.122	-0.00	0.13	1.114
CWU_TSLS- CWU_GKIG	2194	-0.00	0.15	1.127	0.00	0.22	1.587
CWU_TSKF- CWU_GKIG	2194	0.00	0.19	1.187	0.00	0.25	1.593
CWU_GKNA- CWU_2022	2164	0.00	0.07	0.414	-0.00	0.07	0.407
CWU_GKNA- CWU_2021	2146	0.00	0.10	0.552	0.00	0.10	0.554
CWU_GKNA- CWU_2020	2149	0.00	0.12	0.654	-0.00	0.13	0.725
CWU_GKNA- CWU_2019	2163	0.01	0.15	0.824	0.00	0.16	0.856
CWU_GKNA- PBO_2018	2159	0.00	0.21	1.119	0.00	0.22	1.174

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 (mm/yr)	U Mean (mm/yr)	U WRMS (mm/yr)	U NRMS (mm/yr)
CWU_GKNA- CWU_TSLS	2194	0.00	0.18	1.387	-0.03	0.36	0.832
CWU_GKNA- CWU_TSKF	2194	0.00	0.22	1.414	0.03	0.43	0.935
CWU_GKNA- CWU_GKIG	2194	-0.00	0.08	0.449	0.23	0.30	0.554
CWU_TSLS- CWU_TSKF	2726	-0.00	0.13	1.117	0.05	0.36	1.065
CWU_TSLS- CWU_GKIG	2194	-0.01	0.20	1.471	0.26	0.49	1.090
CWU_TSKF- CWU_GKIG	2194	-0.01	0.23	1.484	0.21	0.51	1.088
CWU_GKNA- CWU_2022	2164	-0.00	0.07	0.410	0.01	0.29	0.518
CWU_GKNA- CWU_2021	2146	-0.00	0.10	0.555	-0.05	0.37	0.640
CWU_GKNA- CWU_2020	2149	-0.01	0.12	0.695	-0.11	0.43	0.732
CWU_GKNA- CWU_2019	2163	-0.01	0.16	0.879	-0.08	0.53	0.871
CWU_GKNA- PBO_2018	2159	-0.01	0.22	1.173	0.10	0.70	1.136

Comparison with rotation and translation alignment

CWU_GKNA- CWU_TSLS	2194	0.00	0.18	1.386	-0.03	0.36	0.829
CWU_GKNA- CWU_TSKF	2194	-0.00	0.22	1.412	0.00	0.43	0.931
CWU_GKNA- CWU_GKIG	2194	0.00	0.00	0.024	-0.00	0.00	0.008
CWU_TSLS- CWU_TSKF	2726	-0.00	0.13	1.118	0.02	0.36	1.058
CWU_TSLS- CWU_GKIG	2194	-0.00	0.19	1.376	0.03	0.37	0.824
CWU_TSKF- CWU_GKIG	2194	0.00	0.22	1.404	-0.00	0.43	0.924
CWU_GKNA- CWU_2022	2164	0.00	0.07	0.410	-0.00	0.29	0.514
CWU_GKNA- CWU_2021	2146	0.00	0.10	0.553	-0.02	0.37	0.633
CWU_GKNA- CWU_2020	2149	0.00	0.12	0.690	-0.05	0.42	0.713
CWU_GKNA- CWU_2019	2163	0.00	0.15	0.840	-0.05	0.52	0.860
CWU_GKNA- PBO_2018	2159	0.00	0.21	1.147	0.03	0.68	1.116

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. (The reason there are fewer 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 0.13 and 0.13 mm/yr, respectively, and the height velocity sigma must be less than 0.46 mm/yr.

Soln1 - Soln2	#	N mean (mm/yr)	N WRMS (mm/yr)	N NRMS	E mean (mm/yr)	E WRMS (mm/yr)	E NRMS
CWU_GKNA- CWU_TSLS	792	-0.00	0.06	0.599	-0.00	0.07	0.686
CWU_GKNA- CWU_TSKF	792	-0.00	0.07	0.604	0.00	0.07	0.591
CWU_GKNA- CWU_GKIG	792	-0.06	0.07	0.520	0.04	0.08	0.564
CWU_TSLS- CWU_TSKF	792	0.00	0.07	0.916	0.00	0.08	0.945
CWU_TSLS- CWU_GKIG	792	-0.05	0.09	0.813	0.04	0.10	0.952
CWU_TSKF- CWU_GKIG	792	-0.05	0.10	0.797	0.04	0.10	0.844
CWU_GKNA- CWU_2022	791	0.00	0.05	0.337	-0.00	0.04	0.331
CWU_GKNA- CWU_2021	791	0.01	0.06	0.436	-0.01	0.06	0.459
CWU_GKNA- CWU_2020	792	-0.02	0.07	0.498	0.01	0.07	0.518
CWU_GKNA- CWU_2019	792	-0.04	0.10	0.670	0.02	0.10	0.661
CWU_GKNA- PBO_2018	792	-0.05	0.13	0.840	0.02	0.14	0.908

with rotation and translation alignment

CWU_GKNA- CWU_TSLS	792	0.00	0.06	0.600	0.00	0.07	0.688
CWU_GKNA- CWU_TSKF	792	0.00	0.07	0.603	-0.00	0.07	0.591
CWU_GKNA- CWU_GKIG	792	0.00	0.00	0.029	0.00	0.00	0.032
CWU_TSLS- CWU_TSKF	792	-0.00	0.07	0.919	-0.00	0.08	0.947
CWU_TSLS- CWU_GKIG	792	-0.00	0.06	0.573	-0.00	0.07	0.662
CWU_TSKF- CWU_GKIG	792	-0.00	0.07	0.582	0.00	0.07	0.569
CWU_GKNA- CWU_2022	791	0.00	0.05	0.336	-0.00	0.04	0.331
CWU_GKNA- CWU_2021	791	0.00	0.06	0.432	0.00	0.06	0.457
CWU_GKNA- CWU_2020	792	0.00	0.07	0.471	-0.00	0.08	0.530
CWU_GKNA- CWU_2019	792	0.00	0.09	0.578	-0.00	0.10	0.648
CWU_GKNA- PBO_2018	792	-0.00	0.11	0.761	0.00	0.13	0.887

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	792	-0.00	0.06	0.644	-0.05	0.25	0.766
CWU_GKNA- CWU_TSKF	792	-0.00	0.07	0.597	-0.00	0.30	0.892
CWU_GKNA- CWU_GKIG	792	-0.01	0.07	0.542	0.23	0.29	0.728
CWU_TSLS- CWU_TSKF	792	0.00	0.07	0.931	0.04	0.23	1.009
CWU_TSLS- CWU_GKIG	792	-0.01	0.09	0.885	0.28	0.41	1.235
CWU_TSKF- CWU_GKIG	792	-0.01	0.10	0.821	0.23	0.42	1.221
CWU_GKNA- CWU_2022	791	0.00	0.05	0.334	-0.01	0.20	0.464
CWU_GKNA- CWU_2021	791	0.00	0.06	0.448	-0.07	0.23	0.532
CWU_GKNA- CWU_2020	792	-0.01	0.07	0.508	-0.12	0.28	0.632
CWU_GKNA- CWU_2019	792	-0.01	0.10	0.665	-0.09	0.36	0.780
CWU_GKNA- PBO_2018	792	-0.02	0.13	0.875	0.05	0.51	1.086
Comparison with rotation and translation alignment							
CWU_GKNA- CWU_TSLS	792	0.00	0.06	0.645	-0.03	0.24	0.756
CWU_GKNA- CWU_TSKF	792	0.00	0.07	0.597	0.00	0.30	0.892
CWU_GKNA- CWU_GKIG	792	0.00	0.00	0.030	-0.00	0.00	0.011
CWU_TSLS- CWU_TSKF	792	-0.00	0.07	0.933	0.02	0.22	0.997
CWU_TSLS- CWU_GKIG	792	-0.00	0.07	0.619	0.03	0.24	0.744
CWU_TSKF- CWU_GKIG	792	-0.00	0.07	0.576	-0.00	0.30	0.879
CWU_GKNA- CWU_2022	791	0.00	0.05	0.333	-0.01	0.19	0.459
CWU_GKNA- CWU_2021	791	0.00	0.06	0.445	-0.03	0.22	0.501
CWU_GKNA- CWU_2020	792	0.00	0.07	0.502	-0.06	0.26	0.578
CWU_GKNA- CWU_2019	792	0.00	0.09	0.614	-0.04	0.35	0.755
CWU_GKNA- PBO_2018	792	-0.00	0.12	0.827	0.03	0.51	1.084

Overall, the agreement between the different methods of estimating the velocities is very good, with the WRMS difference in the NE components typically <0.3 mm/yr with the comparison to the CWU 2019-2022 velocities all being less than 0.2 mm/yr, Hz, and 0.53 mm/yr (vertical). The comparison to the 2018 combined CWU and NMT solution is only slightly greater than to the CWU-only solutions. Re-aligning the reference frames makes little difference to the WRMS differences and slightly degrades the vertical differences because the horizontal components carry the most weight in estimating the transformation parameters.

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 the distribution of the stations in the velocity field estimates, we show in Figure 1 the vertical rates of the 2188 stations with standard deviations less than 5 mm/yr. Due to the process noise limits in the solution, only six stations have standard deviations in the vertical rates larger than this value.

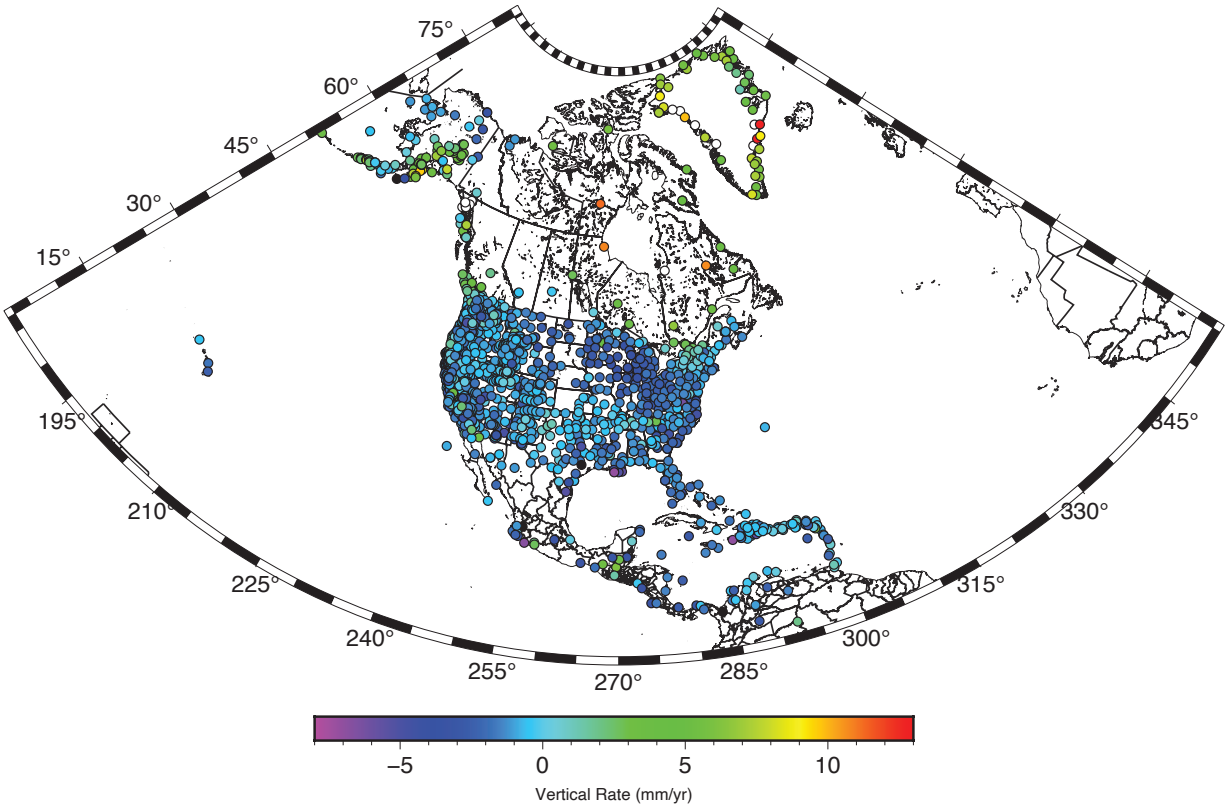

Figure 1: Vertical rate estimates for the 2188 stations in the CWU NAM14 solution with vertical velocity standard deviations of less than 5 mm/yr. (The whole solution contains 2296 stations). The KF time series solutions contain 2657 stations with vertical velocity standard deviations less than 5 mm/yr and 69 stations with standard deviations greater than this.

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 2294 (Dec-30-2023). In the time series analysis, 77 sites are included, but in the GLOBK SINEX file, a combination of 71 stations is included. The six additional sites in the time series analysis have larger systematics that will likely corrupt the combined analysis even with large process noise values assigned to 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 comparison statistics are 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 the combination method and reference frame: LS – least squares, KF – Kalman filter; AN – ANT14, IG – IGS14 rotated to NA. CWU_2022 is last year's solution and is highlighted in yellow. The final entry PBO_2019 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	0.19	1.242	-0.01	0.18	1.284
CWU_GKAN- CWU_TSKF	71	0.00	0.26	1.447	-0.03	0.24	1.445
CWU_GKAN- CWU_GKIG	71	-0.01	0.31	1.601	0.08	0.13	0.722
CWU_TSLS- CWU_TSKF	77	-0.00	0.18	1.319	-0.01	0.17	1.239
CWU_TSLS- CWU_GKIG	71	-0.04	0.36	2.270	0.08	0.23	1.530
CWU_TSKF- CWU_GKIG	71	-0.02	0.39	2.109	0.10	0.30	1.683
CWU_GKAN- CWU_2022	71	-0.00	0.09	0.479	0.02	0.09	0.502
CWU_GKAN- CWU_2021	71	-0.01	0.06	0.323	0.03	0.09	0.496
CWU_GKAN- CWU_2020	71	0.02	0.15	0.752	0.01	0.12	0.673
CWU_GKAN- CWU_2019	71	0.00	0.12	0.616	0.03	0.11	0.599
CWU_GKAN- PBO_2019	32	-0.00	0.12	0.760	0.02	0.12	0.797
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	71	-0.02	0.18	1.196	-0.00	0.17	1.249
CWU_GKAN- CWU_TSKF	71	-0.01	0.24	1.364	-0.02	0.23	1.376
CWU_GKAN- CWU_GKIG	71	0.00	0.00	0.022	0.00	0.00	0.019
CWU_TSLS- CWU_TSKF	77	0.02	0.18	1.301	-0.02	0.16	1.200
CWU_TSLS- CWU_GKIG	71	0.02	0.19	1.208	-0.00	0.19	1.230
CWU_TSKF- CWU_GKIG	71	0.01	0.25	1.363	0.02	0.25	1.372
CWU_GKAN- CWU_2022	71	0.01	0.08	0.438	-0.00	0.08	0.475
CWU_GKAN- CWU_2021	71	0.00	0.06	0.328	0.00	0.08	0.455
CWU_GKAN- CWU_2020	71	-0.00	0.13	0.675	0.00	0.11	0.624
CWU_GKAN- CWU_2019	71	0.01	0.12	0.587	0.01	0.10	0.526
CWU_GKAN- PBO_2019	32	0.03	0.12	0.772	0.00	0.08	0.575

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	-0.00	0.18	1.263	-0.15	0.44	0.915
CWU_GKAN- CWU_TSKF	71	-0.01	0.25	1.446	-0.15	0.56	1.109
CWU_GKAN- CWU_GKIG	71	0.03	0.24	1.242	-0.28	0.73	1.284
CWU_TSLS- CWU_TSKF	77	-0.01	0.18	1.280	0.04	0.31	0.777
CWU_TSLS- CWU_GKIG	71	0.03	0.30	1.936	-0.14	0.77	1.586
CWU_TSKF- CWU_GKIG	71	0.04	0.35	1.908	-0.14	0.92	1.809
CWU_GKAN- CWU_2022	71	0.01	0.09	0.491	0.06	0.26	0.450
CWU_GKAN- CWU_2021	71	0.01	0.08	0.419	-0.00	0.21	0.365
CWU_GKAN- CWU_2020	71	0.01	0.13	0.713	-0.18	0.62	1.037
CWU_GKAN- CWU_2019	71	0.02	0.12	0.608	0.01	0.48	0.822
CWU_GKAN- PBO_2019	32	0.01	0.12	0.779	0.14	0.35	0.759

Comparison with rotation and translation alignment

CWU_GKAN- CWU_TSLS	71	-0.01	0.18	1.223	-0.01	0.41	0.867
CWU_GKAN- CWU_TSKF	71	-0.01	0.24	1.370	0.02	0.54	1.069
CWU_GKAN- CWU_GKIG	71	0.00	0.00	0.020	-0.00	0.00	0.007
CWU_TSLS- CWU_TSKF	77	0.00	0.17	1.251	0.05	0.31	0.761
CWU_TSLS- CWU_GKIG	71	0.01	0.19	1.219	0.01	0.42	0.872
CWU_TSKF- CWU_GKIG	71	0.02	0.25	1.367	-0.01	0.55	1.071
CWU_GKAN- CWU_2022	71	0.00	0.08	0.457	0.03	0.22	0.390
CWU_GKAN- CWU_2021	71	0.00	0.07	0.397	-0.00	0.20	0.345
CWU_GKAN- CWU_2020	71	-0.00	0.12	0.650	-0.00	0.57	0.964
CWU_GKAN- CWU_2019	71	0.01	0.11	0.557	0.04	0.46	0.789
CWU_GKAN- PBO_2019	32	0.01	0.10	0.681	0.07	0.32	0.703

Table 7: Comparison of North and East velocities similar to Table 5, except we limit the stations to those that have horizontal and vertical velocities sigmas, both less than the median horizontal and vertical velocity sigmas. (The reason there are fewer 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 0.18 mm/yr, respectively, and the height velocity sigma must be less than 0.48 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	-0.01	0.09	0.819	-0.01	0.10	1.014
CWU_GKAN- CWU_TSKF	25	-0.04	0.11	0.888	-0.02	0.12	0.972
CWU_GKAN- CWU_GKIG	25	-0.13	0.23	1.637	0.07	0.13	0.972
CWU_TSLS- CWU_TSKF	25	-0.02	0.07	0.775	-0.01	0.09	0.947
CWU_TSLS- CWU_GKIG	25	-0.13	0.26	2.350	0.08	0.16	1.539
CWU_TSKF- CWU_GKIG	25	-0.10	0.26	1.996	0.09	0.18	1.452
CWU_GKAN- CWU_2022	25	0.00	0.05	0.373	0.02	0.05	0.423
CWU_GKAN- CWU_2021	25	-0.01	0.03	0.227	0.02	0.04	0.305
CWU_GKAN- CWU_2020	25	0.01	0.08	0.614	0.01	0.08	0.650
CWU_GKAN- CWU_2019	25	-0.01	0.06	0.441	0.03	0.07	0.517
CWU_GKAN- PBO_2019	18	-0.01	0.08	0.571	0.01	0.09	0.730
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	25	-0.01	0.08	0.746	-0.00	0.09	0.954
CWU_GKAN- CWU_TSKF	25	-0.01	0.08	0.604	-0.01	0.10	0.833
CWU_GKAN- CWU_GKIG	25	0.00	0.00	0.029	-0.00	0.00	0.026
CWU_TSLS- CWU_TSKF	25	0.01	0.06	0.648	-0.01	0.08	0.900
CWU_TSLS- CWU_GKIG	25	0.01	0.08	0.733	0.00	0.10	0.907
CWU_TSKF- CWU_GKIG	25	0.01	0.08	0.586	0.01	0.10	0.810
CWU_GKAN- CWU_2022	25	0.00	0.05	0.354	-0.00	0.05	0.385
CWU_GKAN- CWU_2021	25	0.00	0.03	0.242	0.00	0.03	0.210
CWU_GKAN- CWU_2020	25	0.01	0.07	0.516	0.00	0.07	0.516
CWU_GKAN- CWU_2019	25	0.01	0.06	0.466	0.01	0.05	0.380
CWU_GKAN- PBO_2019	18	0.02	0.08	0.616	0.01	0.05	0.396

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	-0.01	0.09	0.922	-0.11	0.30	0.910
CWU_GKAN- CWU_TSKF	25	-0.03	0.11	0.931	-0.11	0.45	1.269
CWU_GKAN- CWU_GKIG	25	-0.02	0.18	1.346	-0.07	0.48	1.178
CWU_TSLS- CWU_TSKF	25	-0.01	0.08	0.865	0.02	0.25	0.946
CWU_TSLS- CWU_GKIG	25	-0.02	0.22	1.986	0.01	0.54	1.564
CWU_TSKF- CWU_GKIG	25	-0.00	0.22	1.745	0.02	0.74	2.037
CWU_GKAN- CWU_2022	25	0.01	0.05	0.399	0.01	0.08	0.201
CWU_GKAN- CWU_2021	25	0.01	0.04	0.269	-0.03	0.11	0.274
CWU_GKAN- CWU_2020	25	0.01	0.08	0.632	-0.19	0.26	0.617
CWU_GKAN- CWU_2019	25	0.01	0.07	0.481	0.02	0.20	0.481
CWU_GKAN- PBO_2019	18	0.00	0.08	0.655	0.16	0.31	0.778
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	25	-0.01	0.09	0.856	-0.02	0.29	0.867
CWU_GKAN- CWU_TSKF	25	-0.01	0.09	0.727	-0.04	0.41	1.167
CWU_GKAN- CWU_GKIG	25	0.00	0.00	0.028	-0.00	0.00	0.009
CWU_TSLS- CWU_TSKF	25	-0.00	0.07	0.784	-0.01	0.22	0.833
CWU_TSLS- CWU_GKIG	25	0.01	0.09	0.825	0.01	0.30	0.856
CWU_TSKF- CWU_GKIG	25	0.01	0.09	0.707	0.04	0.42	1.154
CWU_GKAN- CWU_2022	25	0.00	0.05	0.370	0.02	0.06	0.146
CWU_GKAN- CWU_2021	25	0.00	0.03	0.227	-0.01	0.10	0.246
CWU_GKAN- CWU_2020	25	0.00	0.07	0.516	-0.00	0.16	0.388
CWU_GKAN- CWU_2019	25	0.01	0.06	0.425	0.01	0.21	0.491
CWU_GKAN- PBO_2019	18	0.01	0.07	0.518	0.06	0.25	0.635

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. Figures 2 and 3 show the horizontal and vertical motions of the 71 sites included in the GLOBK SINEX analysis.

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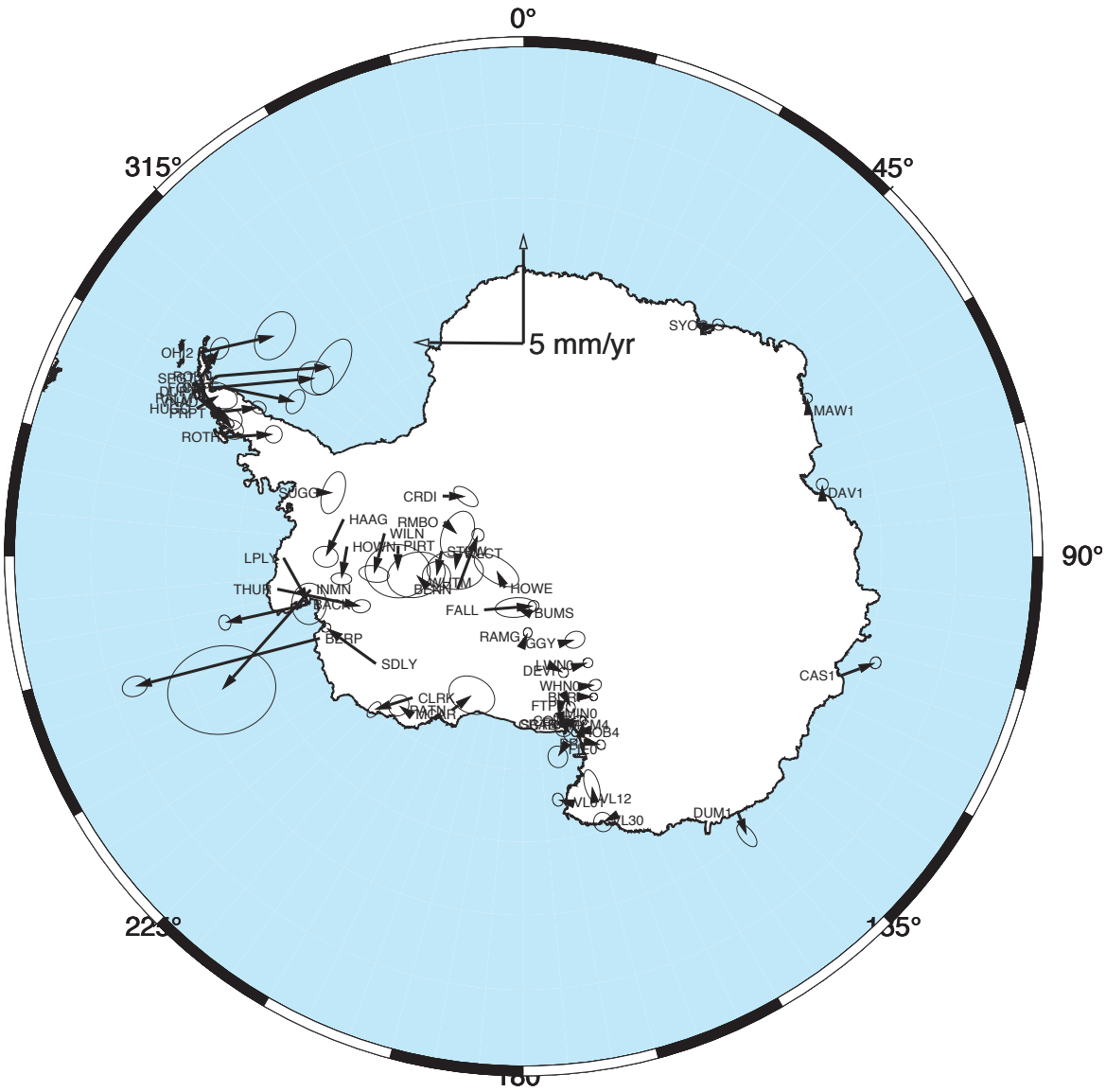

Figure 2: Horizontal motions in the ITRF2014 Antarctica fixed reference frame from the GLOBK SINEX file analysis (GKAN).

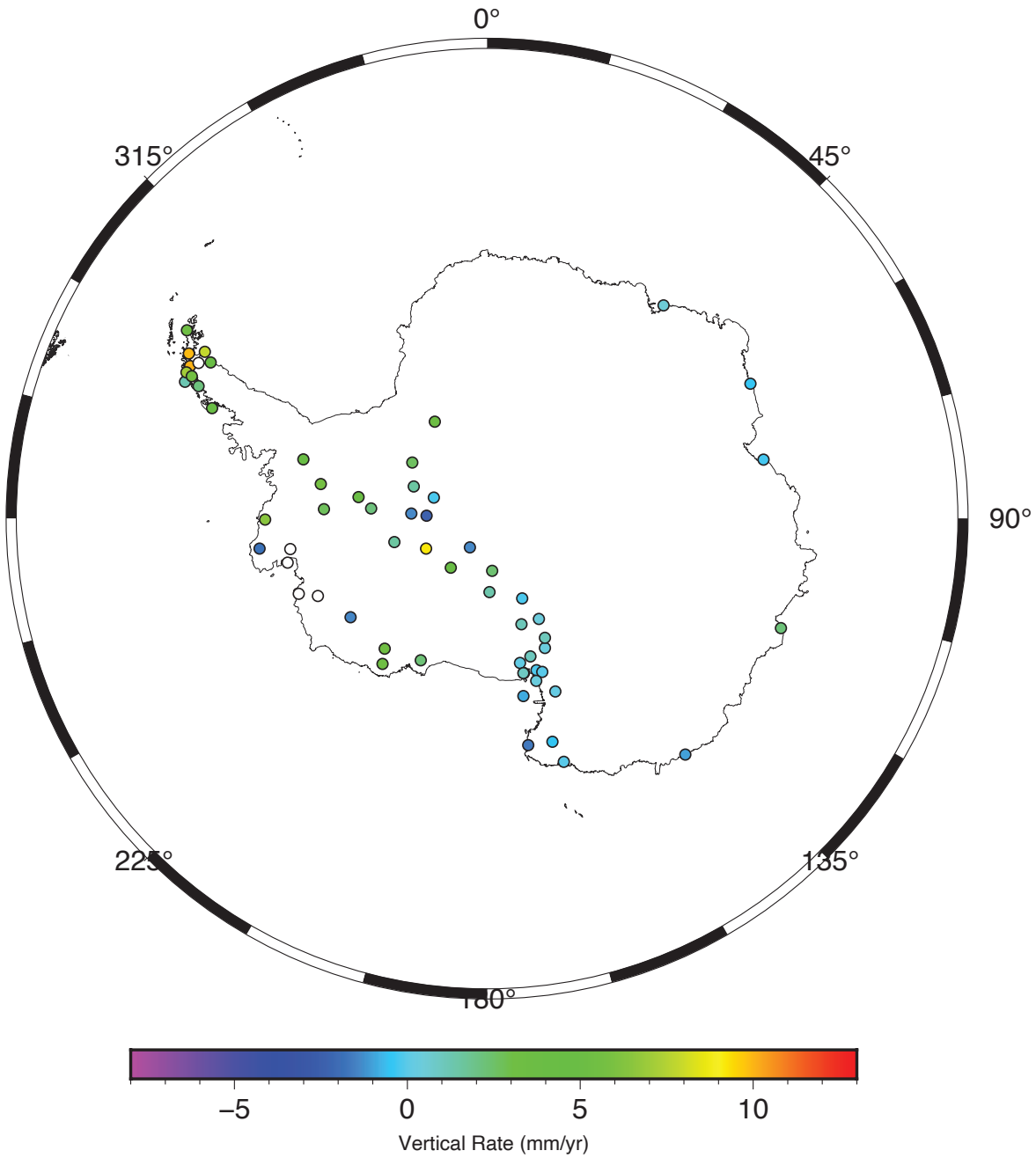

Figure 3: Vertical motions from the GLOBK SINEX file analysis (GKAN). The sites shown with white circles are offset scale and are uplifting at rates as high as 33±1 mm/yr (INMN).