UNAVCO GAGE GNSS Data Product Notice to Users:
Notes on 2020 GAGE CWU NAM14 and ANT14 velocity fields
End GPS week 2083, 2019-12-14
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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 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

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 2020 NA GAGE full velocity solution includes GPS data from GPS week 0834 (Jan-01-1996) to week 2083 (Dec-14-2019) 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 2083 (Dec-14-2019).

The two sets of velocity fields in the GAGE velocity file format have been queued to LDM as cwu.final_igs14.vel.20200113021915, cwu.final_nam14.vel.20200113021915 (NA) and cwu.fanet_ant14.vel.20200114192450, cwu.fanet_igs14.vel.20200114192450 (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. Nineteen stations are excluded from NAM14 based on this criterion (KIOS, SCW2, CASA, TNCY, SMM1, AC09, BLOK, WLHG, BLKM, P656, P323, ELMA, MIDB, FCTF, NTOE, SMM2, MARC, AV05, AC30). Most of these stations have a combination of large systematics and/or short durations of valid data. 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. 542 stations in the NA and 12 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 11669845 station-days. The outlier criteria remove 11637 (0.1%) of CWU station-days of solutions.

NA processing.

The NA processing divides the 2583 stations analyzed into 34 networks each with approximately 80 station locations. With breaks included, there are 9184 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 117 to 357 individual station names to accommodate the discontinuities, with a median number of stations of 181. 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 (2019-12-14 GPS Week 2083 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 on 2019-06-21 and 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 904 stations in the solution. (These stations have velocity standards less than the median standard deviations in north, east and up in all three components, 0.16, 0.16 and 0.57 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 PBO_2018, PBO_2017, and PBO_2015 are the earlier 2018, 2017 and 2015 PBO full solution generated in June 2019, December 2018, November 2015. 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	2583	0.00	0.23	1.443	0.01	0.26	1.630
CWU_GKNA- CWU_TSKF	2583	-0.01	0.29	1.573	0.00	0.31	1.704
CWU_GKNA- CWU_GKIG	2583	0.03	0.05	0.235	0.01	0.06	0.287
CWU_TSLS- CWU_TSKF	2620	-0.01	0.13	1.038	-0.00	0.13	1.041
CWU_TSLS- CWU_GKIG	2583	0.03	0.25	1.446	-0.00	0.28	1.652
CWU_TSKF- CWU_GKIG	2583	0.04	0.31	1.579	0.00	0.33	1.723
CWU_GKNA- PBO_2018	2572	-0.01	0.48	2.273	0.02	0.73	3.485
CWU_GKNA- PBO_2017	2196	0.14	0.43	2.069	0.09	0.42	2.021
CWU_GKNA- PBO_2015	2125	0.10	0.46	2.111	0.07	0.45	2.074
Comparison with rotation and translation alignment							
CWU_GKNA- CWU_TSLS	2583	-0.00	0.23	1.442	0.00	0.26	1.629
CWU_GKNA- CWU_TSKF	2583	-0.00	0.29	1.572	-0.00	0.31	1.703
CWU_GKNA- CWU_GKIG	2583	0.00	0.00	0.019	0.00	0.00	0.019
CWU_TSLS- CWU_TSKF	2620	0.00	0.13	1.035	-0.00	0.13	1.040
CWU_TSLS- CWU_GKIG	2583	0.00	0.25	1.432	-0.00	0.27	1.620
CWU_TSKF- CWU_GKIG	2583	0.00	0.31	1.562	0.00	0.33	1.695
CWU_GKNA- PBO_2018	2572	-0.00	0.48	2.277	-0.00	0.73	3.484
CWU_GKNA- PBO_2017	2196	0.00	0.33	1.570	-0.00	0.36	1.760
CWU_GKNA- PBO_2015	2125	-0.01	0.37	1.712	-0.00	0.42	1.947

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	2583	0.00	0.25	1.540	0.00	0.72	1.348
CWU_GKNA- CWU_TSKF	2583	-0.01	0.30	1.640	-0.00	0.84	1.500
CWU_GKNA- CWU_GKIG	2583	0.02	0.06	0.263	0.26	0.30	0.449
CWU_TSLS- CWU_TSKF	2620	-0.01	0.13	1.040	-0.02	0.43	1.179
CWU_TSLS- CWU_GKIG	2583	0.01	0.27	1.552	0.25	0.80	1.456
CWU_TSKF- CWU_GKIG	2583	0.02	0.32	1.653	0.25	0.90	1.565
CWU_GKNA- PBO_2018	2572	0.00	0.62	2.942	0.22	0.61	0.898

CWU_GKNA-	PBO_2017	2196	0.12	0.42	2.045	0.71	0.94	1.519
CWU_GKNA-	PBO_2015	2125	0.08	0.45	2.093	0.89	1.19	1.689

Comparison with rotation and translation alignment

CWU_GKNA-	CWU_TSLS	2583	-0.00	0.25	1.538	-0.02	0.72	1.349
CWU_GKNA-	CWU_TSKF	2583	-0.00	0.30	1.639	-0.01	0.84	1.496
CWU_GKNA-	CWU_GKIG	2583	0.00	0.00	0.019	-0.00	0.00	0.007
CWU_TSLS-	CWU_TSKF	2620	-0.00	0.13	1.038	-0.00	0.43	1.171
CWU_TSLS-	CWU_GKIG	2583	0.00	0.26	1.529	0.02	0.74	1.345
CWU_TSKF-	CWU_GKIG	2583	0.00	0.32	1.630	0.01	0.86	1.492
CWU_GKNA-	PBO_2018	2572	-0.00	0.62	2.943	0.08	0.57	0.838
CWU_GKNA-	PBO_2017	2196	0.00	0.34	1.667	-0.03	0.54	0.874
CWU_GKNA-	PBO_2015	2125	-0.00	0.40	1.833	0.11	0.74	1.047

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 1291 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 0.16 mm/yr and the height velocity sigma less than 0.57 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		904	-0.01	0.07	0.572	0.00	0.07	0.605
CWU_GKNA-	CWU_TSKF		904	-0.02	0.09	0.640	0.00	0.09	0.656
CWU_GKNA-	CWU_GKIG		904	0.03	0.04	0.248	-0.00	0.05	0.339
CWU_TSLS-	CWU_TSKF		904	-0.01	0.07	0.824	0.00	0.08	0.853
CWU_TSLS-	CWU_GKIG		904	0.03	0.08	0.627	-0.00	0.09	0.682
CWU_TSKF-	CWU_GKIG		904	0.04	0.10	0.699	-0.00	0.10	0.715
CWU_GKNA-	PBO_2018		904	-0.02	0.11	0.658	0.00	0.12	0.722
CWU_GKNA-	PBO_2017		794	0.15	0.28	1.777	0.03	0.19	1.204
CWU_GKNA-	PBO_2015		794	0.13	0.29	1.710	0.02	0.19	1.133

Comparison with rotation and translation alignment

CWU_GKNA-	CWU_TSLS		904	-0.00	0.07	0.565	0.00	0.07	0.602
CWU_GKNA-	CWU_TSKF		904	0.00	0.09	0.632	-0.00	0.09	0.656
CWU_GKNA-	CWU_GKIG		904	0.00	0.00	0.025	0.00	0.00	0.026
CWU_TSLS-	CWU_TSKF		904	0.00	0.07	0.817	-0.00	0.08	0.858
CWU_TSLS-	CWU_GKIG		904	0.00	0.07	0.535	-0.00	0.07	0.565
CWU_TSLS-	CWU_GKIG		904	0.00	0.07	0.535	-0.00	0.07	0.565
CWU_GKNA-	PBO_2018		904	-0.01	0.11	0.662	-0.00	0.12	0.730
CWU_GKNA-	PBO_2017		794	0.00	0.09	0.580	-0.00	0.09	0.595
CWU_GKNA-	PBO_2015		794	-0.00	0.14	0.793	-0.00	0.13	0.769

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	904	-0.00	0.07	0.589	0.01	0.26	0.671
CWU_GKNA-	CWU_TSKF	904	-0.01	0.09	0.648	-0.05	0.33	0.812
CWU_GKNA-	CWU_GKIG	904	0.01	0.05	0.297	0.25	0.29	0.584
CWU_TSLS-	CWU_TSKF	904	-0.00	0.07	0.839	-0.05	0.23	0.883
CWU_TSLS-	CWU_GKIG	904	0.02	0.08	0.655	0.25	0.38	0.960
CWU_TSKF-	CWU_GKIG	904	0.02	0.10	0.707	0.29	0.45	1.073
CWU_GKNA-	PBO_2018	904	-0.01	0.11	0.691	0.19	0.42	0.841
CWU_GKNA-	PBO_2017	794	0.09	0.24	1.518	0.66	0.77	1.715
CWU_GKNA-	PBO_2015	794	0.07	0.25	1.451	0.82	0.95	1.762

Comparison with rotation and translation alignment

CWU_GKNA-	CWU_TSLS	904	0.00	0.07	0.584	-0.01	0.26	0.672
CWU_GKNA-	CWU_TSKF	904	0.00	0.09	0.644	-0.03	0.32	0.800
CWU_GKNA-	CWU_GKIG	904	0.00	0.00	0.025	-0.00	0.00	0.009
CWU_TSLS-	CWU_TSKF	904	0.00	0.07	0.838	-0.02	0.22	0.857
CWU_TSLS-	CWU_GKIG	904	0.00	0.07	0.550	0.01	0.26	0.661
CWU_TSLS-	CWU_GKIG	904	0.00	0.07	0.550	0.01	0.26	0.661
CWU_GKNA-	PBO_2018	904	-0.00	0.11	0.697	0.08	0.38	0.761
CWU_GKNA-	PBO_2017	794	0.00	0.09	0.588	-0.02	0.32	0.704
CWU_GKNA-	PBO_2015	794	-0.00	0.13	0.781	0.08	0.40	0.751

Over all the agreement between the different methods of estimating the velocities are very good with the WRMS difference in the NE components typically <0.4 mm/yr with the comparison to the PBO 2018, PBO 2017, and PBO 2015 velocity all being about 0.5 mm/yr. The height WRMS differences are less than 1.0 mm/yr with the comparisons to the earlier solutions being less than 1.2 mm/yr when no frame re-alignment is used and 0.7 mm/yr when the frames are re-aligned. The NRMS scatter of the differences is typically less than 2 for the different analysis methods and less than 3.5 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 2541 stations which have vertical rates with standard deviations less than 5 mm/yr. Figure 2 shows the rates in California.

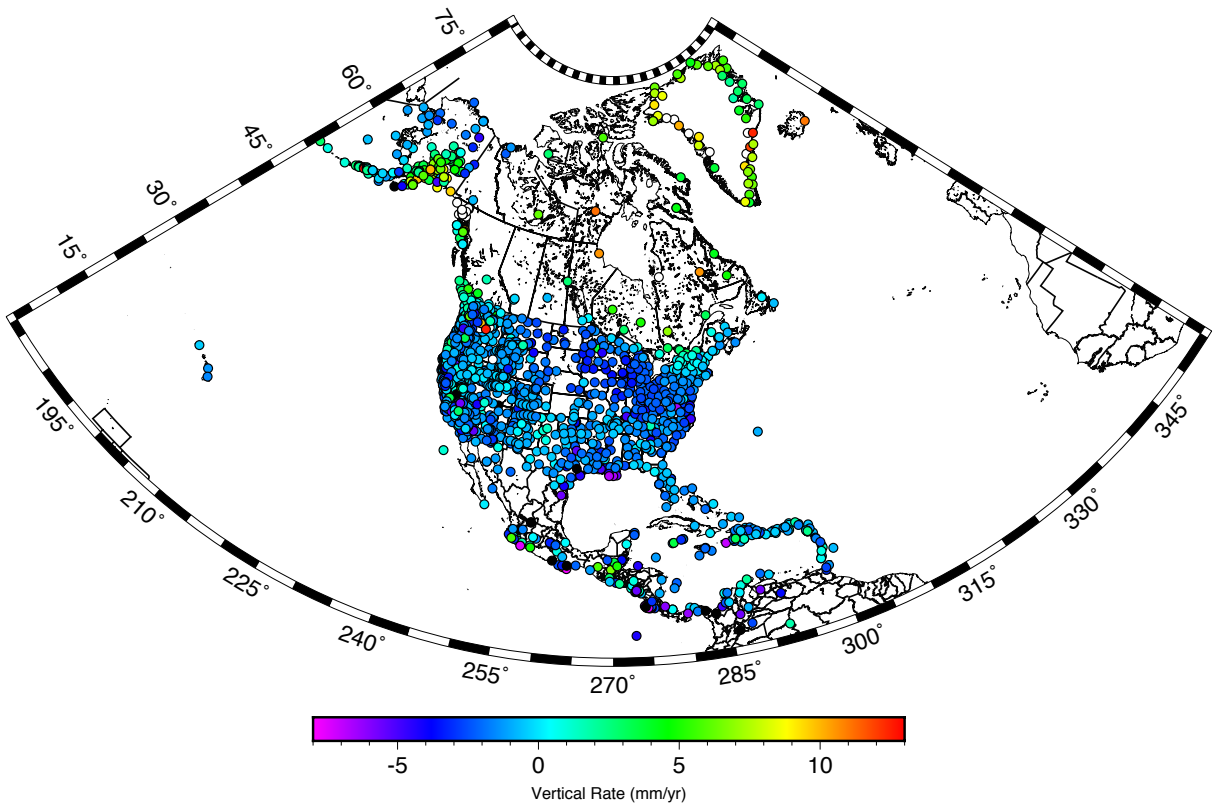

Figure 1: Vertical rate estimates for the 2541 stations in the CWU NAM14 solution with vertical velocity standard deviations of less than 5 mm/yr.

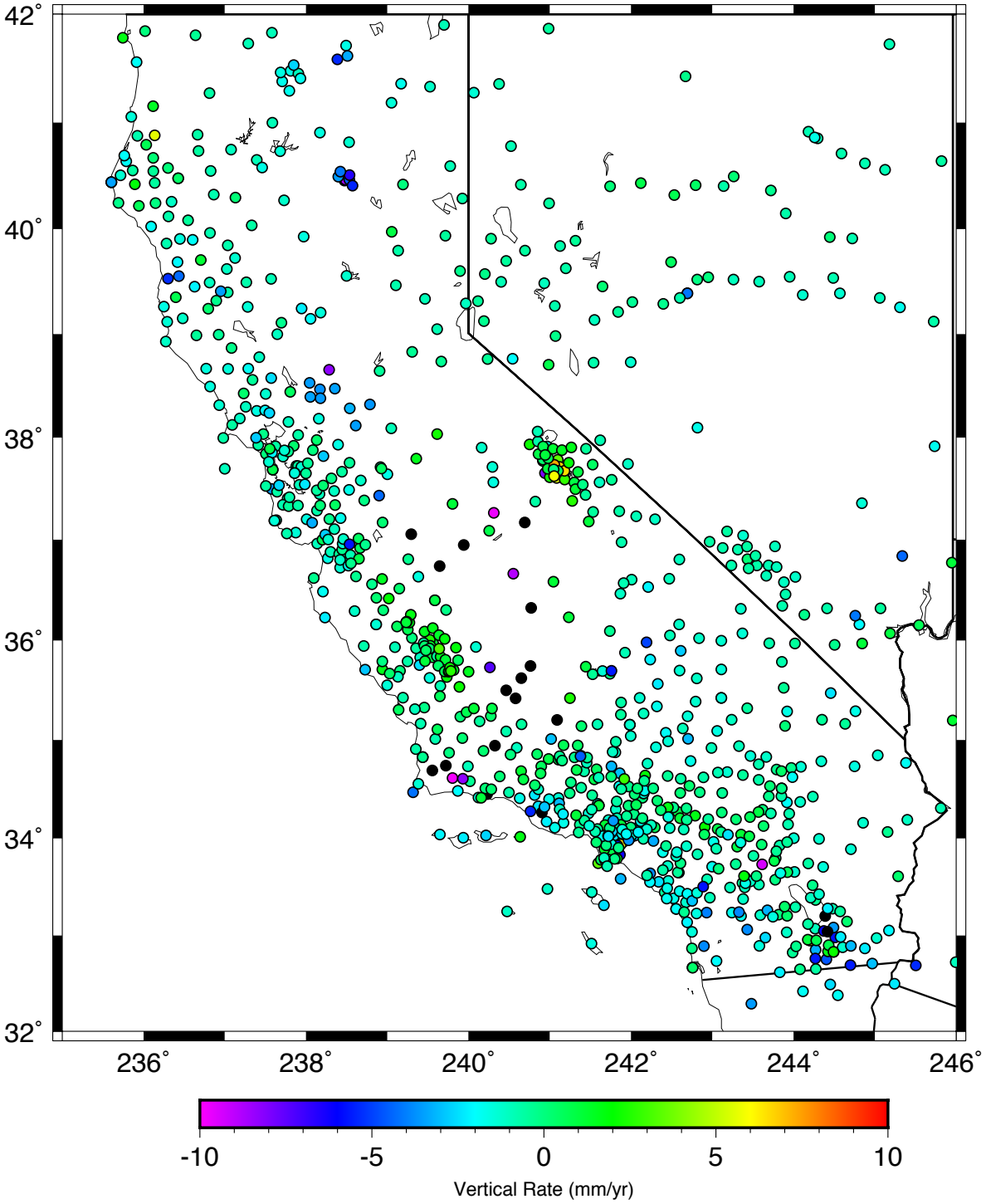

Figure 2: Vertical motions in California. Black symbols show point subsiding faster than 10 mm/yr.

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 2083 (Dec-14-2019). In the time series analysis, 77 sites are included but in the GLOBK SINEX file combination of 60 stations are included. The 17 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. 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	60	0.03	0.19	1.245	-0.04	0.18	1.271
CWU_GKAN- CWU_TSKF	60	0.01	0.27	1.495	-0.04	0.20	1.186
CWU_GKAN- CWU_GKIG	60	-0.03	0.31	1.606	0.09	0.13	0.687
CWU_TSLS- CWU_TSKF	77	-0.01	0.15	0.962	0.01	0.13	0.852
CWU_TSLS- CWU_GKIG	60	-0.07	0.36	2.204	0.12	0.25	1.554
CWU_TSKF- CWU_GKIG	60	-0.03	0.37	1.953	0.13	0.27	1.441
CWU_GKAN- PBO_2018	57	0.02	0.12	0.655	-0.00	0.14	0.777
Comparison with rotation and translation alignment							
CWU_GKAN- CWU_TSLS	60	-0.01	0.17	1.163	-0.01	0.18	1.248
CWU_GKAN- CWU_TSKF	60	-0.01	0.24	1.365	-0.03	0.20	1.186
CWU_GKAN- CWU_GKIG	60	-0.00	0.00	0.019	-0.00	0.00	0.023
CWU_TSLS- CWU_TSKF	77	0.00	0.14	0.930	-0.02	0.12	0.830
CWU_TSLS- CWU_GKIG	60	0.01	0.19	1.147	0.01	0.20	1.233
CWU_TSKF- CWU_GKIG	60	0.02	0.25	1.331	0.03	0.22	1.176
CWU_GKAN- PBO_2018	57	0.02	0.11	0.598	-0.01	0.13	0.756

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	60	-0.01	0.18	1.258	-0.14	0.36	0.785
CWU_GKAN- CWU_TSKF	60	-0.01	0.24	1.349	-0.12	0.46	0.949
CWU_GKAN- CWU_GKIG	60	0.03	0.24	1.235	-0.23	0.61	1.087
CWU_TSLS- CWU_TSKF	77	-0.00	0.14	0.909	0.03	0.28	0.669
CWU_TSLS- CWU_GKIG	60	0.03	0.31	1.907	-0.10	0.54	1.138
CWU_TSKF- CWU_GKIG	60	0.05	0.32	1.716	-0.12	0.73	1.448

CWU_GKAN-	PBO_2018	57	0.01	0.13	0.719	|	0.04	0.43	0.820
Comparison with rotation and translation alignment									
CWU_GKAN-	CWU_TSLS	60	-0.01	0.18	1.207	|	0.02	0.33	0.708
CWU_GKAN-	CWU_TSKF	60	-0.02	0.22	1.279	|	0.04	0.46	0.931
CWU_GKAN-	CWU_GKIG	60	-0.00	0.00	0.021	|	-0.00	0.00	0.007
CWU_TSLS-	CWU_TSKF	77	-0.01	0.13	0.881	|	0.03	0.27	0.640
CWU_TSLS-	CWU_GKIG	60	0.01	0.19	1.191	|	-0.00	0.34	0.700
CWU_TSKF-	CWU_GKIG	60	0.02	0.23	1.256	|	-0.02	0.46	0.918
CWU_GKAN-	PBO_2018	57	0.00	0.12	0.681	|	0.05	0.34	0.654

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 30 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 0.49 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	20	-0.00	0.11	1.013	-0.05	0.08	0.801
CWU_GKAN-		CWU_TSKF	20	-0.06	0.13	0.975	-0.04	0.10	0.837
CWU_GKAN-		CWU_GKIG	20	-0.17	0.25	1.776	0.09	0.13	0.955
CWU_TSLS-		CWU_TSKF	20	-0.05	0.09	0.862	0.01	0.06	0.667
CWU_TSLS-		CWU_GKIG	20	-0.17	0.31	2.651	0.14	0.17	1.533
CWU_TSKF-		CWU_GKIG	20	-0.11	0.28	2.054	0.13	0.19	1.420
CWU_GKAN-		PBO_2018	20	0.02	0.08	0.568	-0.01	0.05	0.392
Comparison with rotation and translation alignment									
CWU_GKAN-		CWU_TSLS	20	-0.00	0.10	0.961	0.00	0.04	0.446
CWU_GKAN-		CWU_TSKF	20	-0.02	0.10	0.751	-0.02	0.08	0.675
CWU_GKAN-		CWU_GKIG	20	-0.00	0.00	0.024	-0.00	0.00	0.034
CWU_TSLS-		CWU_TSKF	20	-0.01	0.07	0.666	-0.01	0.06	0.662
CWU_TSLS-		CWU_GKIG	20	0.00	0.11	0.911	-0.00	0.04	0.396
CWU_TSKF-		CWU_GKIG	20	0.02	0.10	0.713	0.02	0.08	0.637
CWU_GKAN-		PBO_2018	20	0.00	0.04	0.304	-0.00	0.04	0.284

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	20	-0.03	0.09	0.913	-0.06	0.16	0.469
CWU_GKAN-		CWU_TSKF	20	-0.05	0.12	0.909	-0.04	0.24	0.675
CWU_GKAN-		CWU_GKIG	20	-0.04	0.20	1.426	-0.08	0.38	0.947
CWU_TSLS-		CWU_TSKF	20	-0.01	0.07	0.771	0.03	0.15	0.549
CWU_TSLS-		CWU_GKIG	20	-0.01	0.25	2.166	-0.05	0.34	0.989

CWU_TSKF-	CWU_GKIG	20	0.01	0.24	1.766	-0.06	0.47	1.277
CWU_GKAN-	PBO_2018	20	0.01	0.06	0.488	-0.01	0.22	0.575

Comparison with rotation and translation alignment

CWU_GKAN-	CWU_TSLS	20	-0.00	0.08	0.749	-0.00	0.16	0.467
CWU_GKAN-	CWU_TSKF	20	-0.02	0.09	0.714	-0.05	0.23	0.645
CWU_GKAN-	CWU_GKIG	20	-0.00	0.00	0.030	-0.00	0.00	0.010
CWU_TSLS-	CWU_TSKF	20	-0.01	0.06	0.664	-0.04	0.14	0.510
CWU_TSLS-	CWU_GKIG	20	-0.00	0.08	0.702	0.01	0.17	0.476
CWU_TSKF-	CWU_GKIG	20	0.02	0.09	0.676	0.05	0.24	0.644
CWU_GKAN-	PBO_2018	20	0.00	0.04	0.294	0.03	0.20	0.527

The agreement between the different analysis methods and earlier combined PBO solutions is at the 0.3 mm/yr and 0.7 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 Figure 3 and 4 we show the horizontal and vertical motions of the 60 sites included in the GLOBK SINEX analysis.

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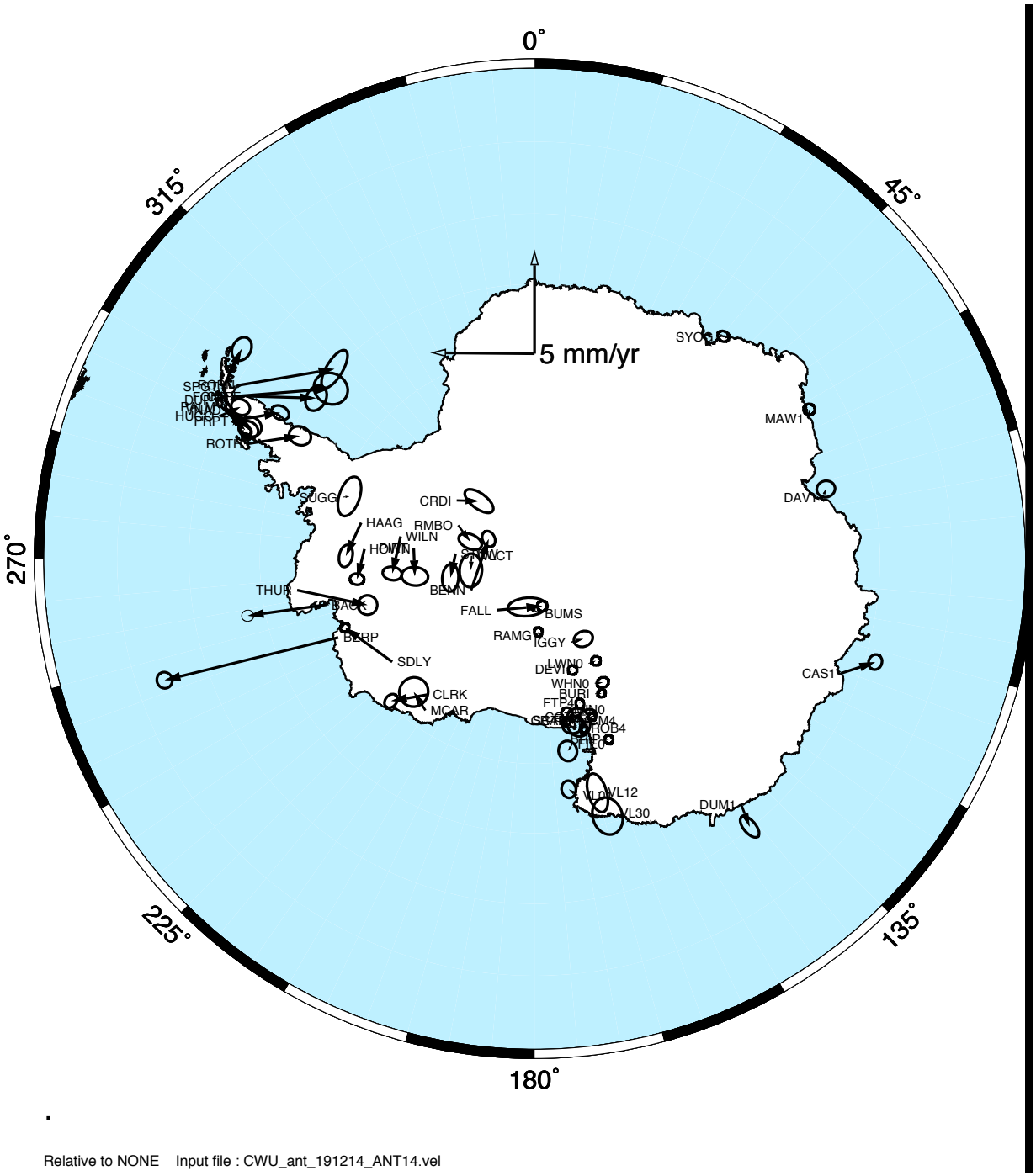

Figure 4: Horizontal motions in the ITRF2014 Antarctica fixed reference frame from the GLOBK SINEX file analysis (GKAN).

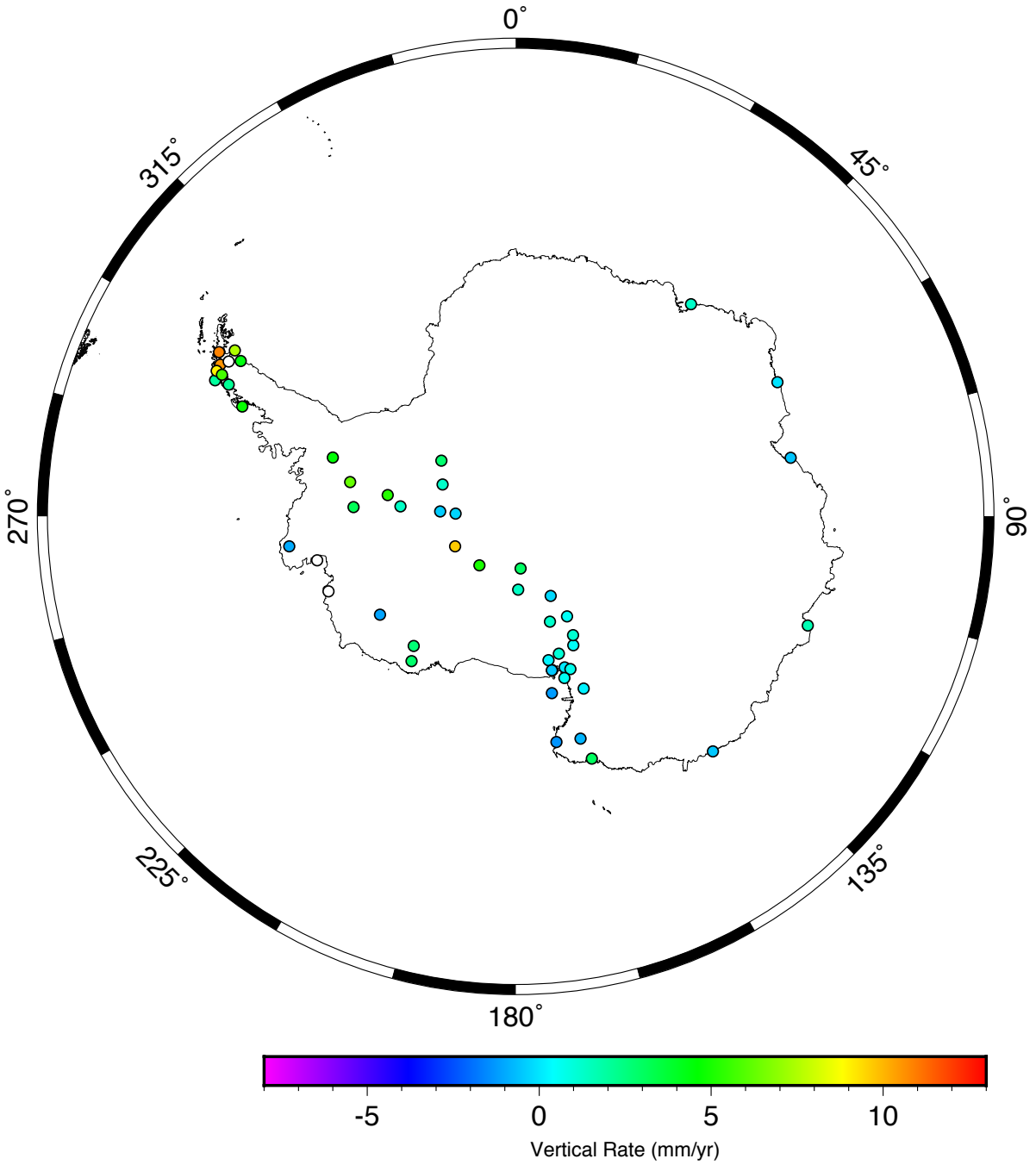

Figure 5: Vertical motions from the GLOBK SINEX file analysis (GKAN).