Note on the 2015 PBO Velocity field to Week 1870 2015-11-14

The complete analysis of the full GAGE velocity field generated from SINEX files (i.e., incorporating full variance covariance matrices and allowing re-alignment of the reference frame for the velocity field) is now being released. The number of sites in these solutions has grown so large that the run-time has become excessive and we are now generating these velocity solutions using a network approach similar to the methods used to create networks for GAMIT processing of large networks. The process noise models, in the form of random walk time-step variances or process noise (RWPN) are given in All_PBO.rw. These values are generated by analysis of the position residuals from fitting the time series for each site. Sites 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 sites. Seven sites are excluded based on this criterion (AC30, AV05, BOMG, P323, P656, SMM1, TNMZ). Most of these sites have a combination of large systematics and/or short durations of valid data. We also impose a minimum RWPN value of 0.05 mm^2/yr. 563 sites 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. The tsfit solution also generates a list of site 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 site position estimates is given in All_PBO_edits.eq. These edits can by AC or for both ACs. The total GAGE time series contain 7418670 station-days. The outlier criteria remove 8339 (0.11%) of NMT and 31372 (0.42%) of CWU station-days of solutions. Because of the long run time of these SINEX velocity solutions, they are currently run using day 3 of each week (i.e., one day per week). When the correlated noise models are used including the additional days of the week has little effect on the estimates of the velocities or their standard deviations i.e., comparison of results from different days of the week or using all seven days in the week show differences small compared the standard deviations of the estimates.

The processing divides the ~2137 sites analyzed into 29 networks each with approximately 77 site locations. (The final number of estimated parameters for each network depends on the number of breaks needed at each site. The networks need from 99 to 288 individual site names to accommodate the discontinuities). There is no overlap between the sites in the first 28 networks. A 29th network is created to tie all the other 28 networks into a single solution. To form the sites in the 29th network, three sites for each network are chosen so as to minimize the trace of the covariance matrix of the estimates of rotation and translation using these sites. Weights assigned to each site in accord with the expected variance of the velocity estimate for the site (i.e., combination of the RWPN and duration of data at the site). If equal weights are given to each site, this algorithm is the same as choosing the three sites that cover the largest area. The details of the sites in each network are given in All_PBO_netsel.use. The analyses of the 29 networks can be run in parallel and takes a few hours to run. The combination of the 29 networks uses ~9 Gbytes of memory and the NMT and CWU combination, along the equating of velocities (with a constraint of ±0.01 mm/yr) at sites with discontinuities takes about a day of CPU time. The NMT and CWU velocity solutions are then merged to form the PBO solution combined solution. This combination uses ~18Gb of memory. 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 NAM08 frame using ~1072 sites in our hierarchical list of reference frame sites; (2) A North America frame aligned to IGb08 rotated into the North America frame using the 37 sites original used in ITRF2008 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 and current day (2015-11-14 GPS Week 1870 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. The current NAM08 frame was originally aligned to the reference frame using data through August of 2014 -- about a year and half ago. Tables 1 and 2 compare the WRMS and NRMS scatters of the differences between the velocity estimates obtained by the two GAGE ACs and the combination of the two ACs using different analysis methods. Table 1's caption explains the naming scheme used to describe the solutions. There are the three analysis centers, NMT, CWU and their combination PBO. 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 monthly GAGE SNAPSHOT fields. The GK analysis can be aligned to the current NAM08 frame (NA) or be realigned to the IGb08 frame (IG). In all analyses, the same process noise models, discontinuities and post-seismic non-linear models (based on time series analyses) are used. The comparisons do not re-align the velocity fields in any way. The RMS values are based on the simple difference between the estimates. The numbers of stations do not match between the analyses because the GK analyses exclude sites with large process noise values. Tables 3 and 4 show the same type of comparison when we restrict the sites to the best 706 in the solution. The NRMS values are very consistent with those in Tables 1 and 2 suggesting that even the sites with the smallest sigma match in accordance with their sigmas.

Over all the agreement between the different methods of estimating the velocities are very good with the WRMS difference in the NE components typically <0.2 mm/yr (including comparison to the PBO 2014 velocity solution) and in height less than 0.7 mm/yr. The NRMS scatter of the differences is typically less than unity showing that the error bars are of the somewhat larger than the differences. The comparison to 2014 solution does have NRMS values a little larger than unity.

The official PBO velocity solution is aligned to our current NAM08 frame to keep consistency of the results and to avoid discontinuities. The current IGb08 is now about

5-years old and will soon be replaced by ITRF2014 (probably early 2016). When the new ITRF is released, we will then re-evaluate aligning to the new ITRF.

Table 1: Comparison of North and East velocities between different velocity field determination methods. No transformation parameters between the fields have been estimated. The codes for the solutions are: CCC_TTYY where CCC is the center NMT, 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 – NAM08, IG – IGb08 rotated to NA. The final entry PBO_2014 is the current PBO full solution generated in November 2014. # is the number of common sites in the solutions.

Soln1 - Soln2	#	N mean (mm)	N WRMS (mm)	N NRMS	E mean (mm)	E WRMS (mm)	E NRMS
PBO_GKNA-CWU_GKNA	2130	-0.01	0.06	0.259	-0.00	0.06	0.262
PBO_GKNA-NMT_GKNA	2136	0.01	0.05	0.221	-0.00	0.05	0.246
CWU_GKNA-NMT_GKNA	2129	0.01	0.10	0.461	0.00	0.11	0.495
PBO_GKNA-PBO_TSLS	2137	-0.01	0.14	0.821	0.00	0.14	0.817
PBO_GKNA-PBO_TSKF	2130	-0.01	0.15	0.800	0.00	0.14	0.750
PBO_GKNA-CWU_TSLS	2130	-0.00	0.15	0.879	-0.00	0.15	0.891
PBO_GKNA-CWU_TSKF	2123	-0.01	0.16	0.804	-0.00	0.15	0.765
PBO_GKNA-NMT_TSLS	2136	-0.00	0.16	0.955	0.00	0.16	0.957
PBO_GKNA-NMT_TSKF	2128	-0.02	0.17	0.876	-0.00	0.16	0.841
PBO_GKNA-PBO_GKIG	2137	-0.01	0.07	0.333	0.22	0.24	1.096
PBO_GKNA-CWU_GKIG	2130	-0.03	0.10	0.460	0.22	0.25	1.149
PBO_GKNA-NMT_GKIG	2136	-0.01	0.08	0.369	0.20	0.23	1.067
PBO_GKNA-PBO_2014	2066	-0.03	0.19	1.163	-0.00	0.20	1.169

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

Soln1 - Soln	#	Hz Mean (mm)	HzWRMS (mm)	HzNRMS	U Mean (mm)	U WRMS (mm)	U NRMS
PBO_GKNA-CWU_GKNA	2130	-0.00	0.06	0.261	0.04	0.24	0.349
PBO_GKNA-NMT_GKNA	2136	0.00	0.05	0.234	-0.03	0.18	0.272
CWU_GKNA-NMT_GKNA	2129	0.01	0.10	0.478	-0.07	0.40	0.593
PBO_GKNA-PBO_TSLS	2137	-0.00	0.14	0.819	0.03	0.42	0.769
PBO_GKNA-PBO_TSKF	2130	-0.01	0.15	0.775	0.12	0.49	0.847
PBO_GKNA-CWU_TSLS	2130	-0.00	0.15	0.885	-0.00	0.50	0.892
PBO_GKNA-CWU_TSKF	2123	-0.01	0.15	0.785	0.07	0.51	0.870
PBO_GKNA-NMT_TSLS	2136	-0.00	0.16	0.956	-0.27	0.66	1.177
PBO_GKNA-NMT_TSKF	2128	-0.01	0.17	0.859	-0.34	0.70	1.197
PBO_GKNA-PBO_GKIG	2137	0.10	0.18	0.810	-0.24	0.27	0.398
PBO_GKNA-CWU_GKIG	2130	0.10	0.19	0.875	-0.19	0.32	0.465

PBO_GKNA-NMT_GKIG	2136	0.10	0.17	0.799	-0.30	0.38	0.560
PBO_GKNA-PBO_2014	2066	-0.02	0.19	1.166	-0.05	0.55	1.008

Table 3: Comparison of North and East velocities similar to Table 1 except we limit the sites to those that have horizontal and vertical velocities sigmas both less than the median horizontal and vertical velocity sigmas. (Reason there are less than 1065 sites is because both horizontal and vertical sigma conditions must be satisfied.)

Soln 1- Soln 2	#	N mean (mm)	N WRMS (mm)	N NRMS	E mean (mm)	E WRMS (mm)	E NRMS
PBO_GKNA-CWU_GKNA	706	-0.01	0.04	0.229	-0.00	0.04	0.257
PBO_GKNA-NMT_GKNA	706	0.01	0.03	0.207	-0.00	0.04	0.245
CWU_GKNA-NMT_GKNA	706	0.01	0.07	0.425	0.00	0.08	0.494
PBO_GKNA-PBO_TSLS	706	-0.01	0.10	0.786	0.01	0.09	0.738
PBO_GKNA-PBO_TSKF	706	-0.02	0.10	0.721	0.01	0.09	0.613
PBO_GKNA-CWU_TSLS	706	-0.01	0.10	0.826	0.01	0.10	0.772
PBO_GKNA-CWU_TSKF	706	-0.02	0.10	0.707	0.01	0.09	0.602
PBO_GKNA-NMT_TSLS	706	-0.01	0.10	0.847	0.01	0.10	0.774
PBO_GKNA-NMT_TSKF	706	-0.02	0.11	0.750	0.01	0.09	0.628
PBO_GKNA-PBO_GKIG	706	-0.00	0.07	0.396	0.22	0.24	1.440
PBO_GKNA-CWU_GKIG	706	-0.02	0.08	0.484	0.23	0.25	1.480
PBO_GKNA-NMT_GKIG	706	0.00	0.07	0.420	0.21	0.23	1.403
PBO_GKNA-PBO_2014	706	-0.03	0.11	0.903	0.01	0.12	0.967

Table 4: Same as Table 3 except for the combined horizontal and vertical comparison.

Soln 1- Soln 2	#	Hz Mean (mm)	HzWRMS (mm)	HzNRMS	U Mean (mm)	U WRMS (mm)	U NRMS
PBO_GKNA-CWU_GKNA	706	-0.00	0.04	0.243	0.02	0.16	0.318
PBO_GKNA-NMT_GKNA	706	0.00	0.04	0.227	-0.02	0.13	0.260
CWU_GKNA-NMT_GKNA	706	0.01	0.07	0.461	-0.04	0.28	0.561
PBO_GKNA-PBO_TSLS	706	-0.00	0.09	0.763	-0.02	0.30	0.741
PBO_GKNA-PBO_TSKF	706	-0.00	0.10	0.670	0.07	0.37	0.861
PBO_GKNA-CWU_TSLS	706	-0.00	0.10	0.799	-0.06	0.35	0.828
PBO_GKNA-CWU_TSKF	706	-0.00	0.10	0.657	0.01	0.37	0.842
PBO_GKNA-NMT_TSLS	706	-0.00	0.10	0.811	-0.24	0.55	1.303
PBO_GKNA-NMT_TSKF	706	-0.01	0.10	0.692	-0.29	0.58	1.328
PBO_GKNA-PBO_GKIG	706	0.11	0.18	1.056	-0.23	0.25	0.497
PBO_GKNA-CWU_GKIG	706	0.11	0.19	1.101	-0.19	0.26	0.508
PBO_GKNA-NMT_GKIG	706	0.11	0.17	1.036	-0.28	0.33	0.659
PBO_GKNA-PBO_2014	706	-0.01	0.12	0.936	-0.07	0.36	0.882