Influence of Changing GPS Antenna Calibrations on EPN Station Coordinates

O. Khoda[1,2], C. Bruyninx[1]

Abstract

Since GPS Week 1400 the IGS (International GNSS Service) has switched to the usage of absolute antenna Phase Centre Variations (PCV) for the routine generation of its precise satellite orbits and station coordinates. The EPN started using the absolute phase center models simultaneously with the IGS. In order to evaluate the influence of the usage of the new absolute PCV (APCV) with respect to the previous relative PCV (RPCV) on the EPN site coordinates we have selected two subsets of stations for which absolute robot calibrations are available: the first, only EPN stations, and, the second, IGS reference frame stations and some EPN stations. We have processed these networks twice using once relative and once absolute PCVs and we investigated the coordinate differences between APCV and RPCV solutions on regional and global levels with respect to their stability in time, and the (lack of) agreement between the offsets obtained at different stations for the same antenna/radome combination.

Introduction

Since GPS Week 1400 the IGS (International GNSS Service) has adopted the absolute PCVs (APCV) for its routine generation of precise satellite orbits and station coordinates (*Gendt, 2006*). Until this date (November 5, 2006) relative elevation–dependent PCVs (RPCV) were applied within the IGS network and the EUREF Permanent GPS Network (EPN). The relative PCV model was based on the arbitrary assumption that the PCVs of the reference antenna *AOAD/M_T* are zero that is not true in fact. And when satellites are seen at relevantly different angles by the two distant stations the different errors on the relative PCV corrections at each of the stations are introduced. As a result systematic errors show up. Moreover, the relative PCVs are only valid for elevation angles above 10°, so they cannot be used for processing of observations for satellites with low elevation angles. In addition, the behavior of the satellite antennae is almost ignored. The absolute offsets and PCVs for the receiver antennae were determined by means of a robotic system developed by the University of Hanover and the company *Geo++*, which include azimuthal values and elevations down to 0°. These absolute PCVs also allowed to determine absolute satellite antenna offsets and PCVs. So, a complete and consistent set of absolute PCVs for both tracking and satellite antennae is now available.

The EPN started using the absolute phase center models simultaneously with the IGS because the EPN strives complete consistency with the IGS standards and models as the European densification of the IGS global network.

Methodology

In order to evaluate the influence of the usage of absolute PCV with respect to relative PCV on the EPN site coordinates we have selected two subsets of stations for which absolute robot calibrations are available. The first set, regional, in the beginning of GPS week 1400 included 134 EPN stations with 23 different antenna/radome combinations (Fig. 1, Table 1). For the second, global, set we chose all IGS reference frame stations equipped with antenna/radome combinations with known true absolute calibrations and some additional station in Europe (Fig. 2–3).

Both networks were processed twice using once relative and once absolute PCVs with the *Bernese GPS Software Version 5.0 (Dach et al., 2007)* according to the standard procedure used in the ROB Local Analyses Center. The reference frame was realized using minimal constraints with the IGS reference frame stations which were included in the networks.

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[1] Royal Observatory of Belgium, Av. Circulaire 3, B-1180 Brussels, Belgium

[2] Main Astronomical Observatory of the National Academy of Sciences of Ukraine, Ac. Zabolotny Str. 27, 03680 Kiev, Ukraine, oleg@mao.kiev.ua

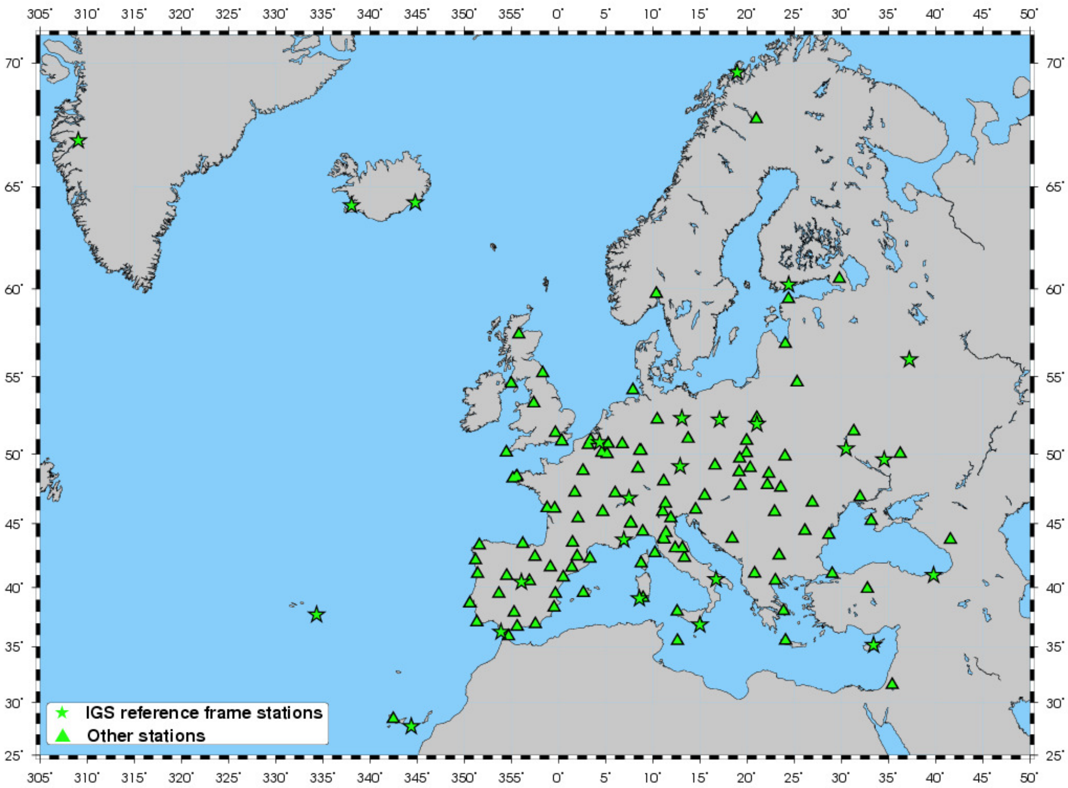

Figure 1 – EPN stations equipped with antenna/radome combinations with known true absolute PCV calibrations

Antenna	Dome	Number of Stations
AOAD/M_B	NONE	1
AOAD/M_T	NONE	15
ASH700936A_M	NONE	3
ASH700936C_M	SNOW	1
ASH700936D_M	NONE	1
ASH700936D_M	SNOW	8
ASH700936E	NONE	1
ASH700936E	SNOW	2
ASH701073.3	NONE	1
ASH701945B_M	NONE	4
ASH701945C_M	NONE	5
ASH701945C_M	SNOW	5
ASH701945E_M	NONE	2
ASH701946.2	NONE	1
JPSREGANT_DD_E	NONE	3
LEIAT504	LEIS	17
LEIAT504	NONE	6
TRM14532.00	NONE	2
TRM22020.00+GP	NONE	1
TRM29659.00	NONE	36
TRM29659.00	TCWD	11
TRM41249.00	NONE	7
TRM55971.00	NONE	1

Table 1 – Number of EPN stations for each antenna/radome combination

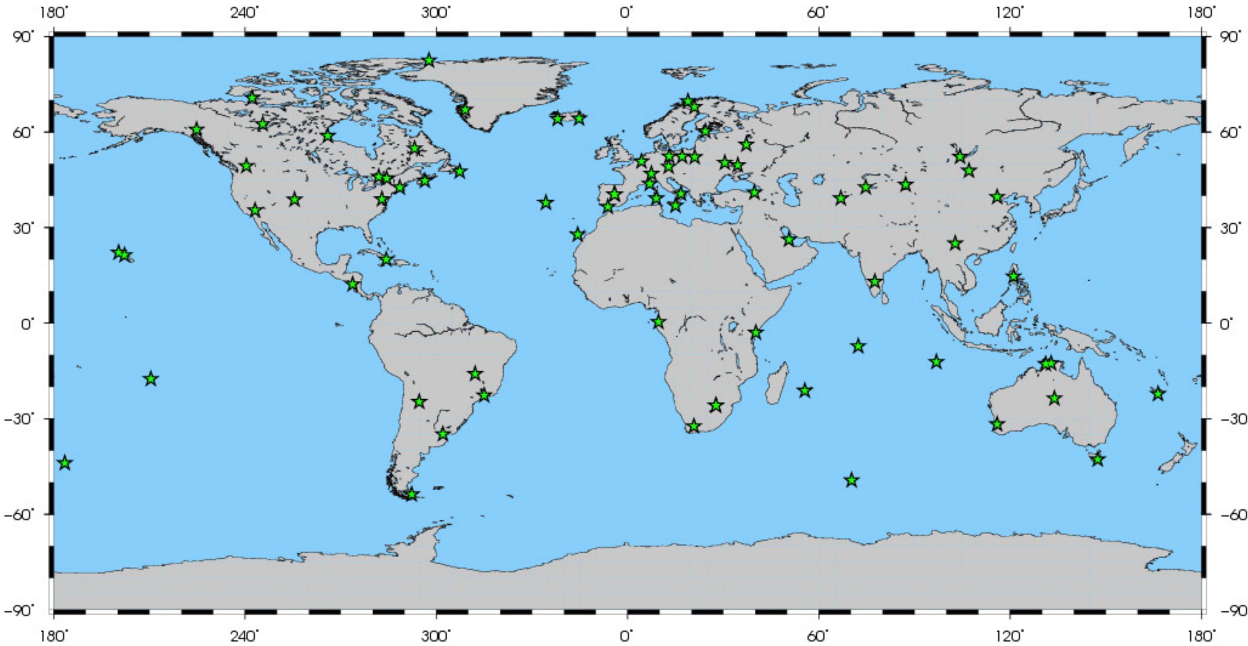

Figure 2 – IGS Reference Frame stations equipped with antenna/radome combinations with known true absolute PCV calibrations

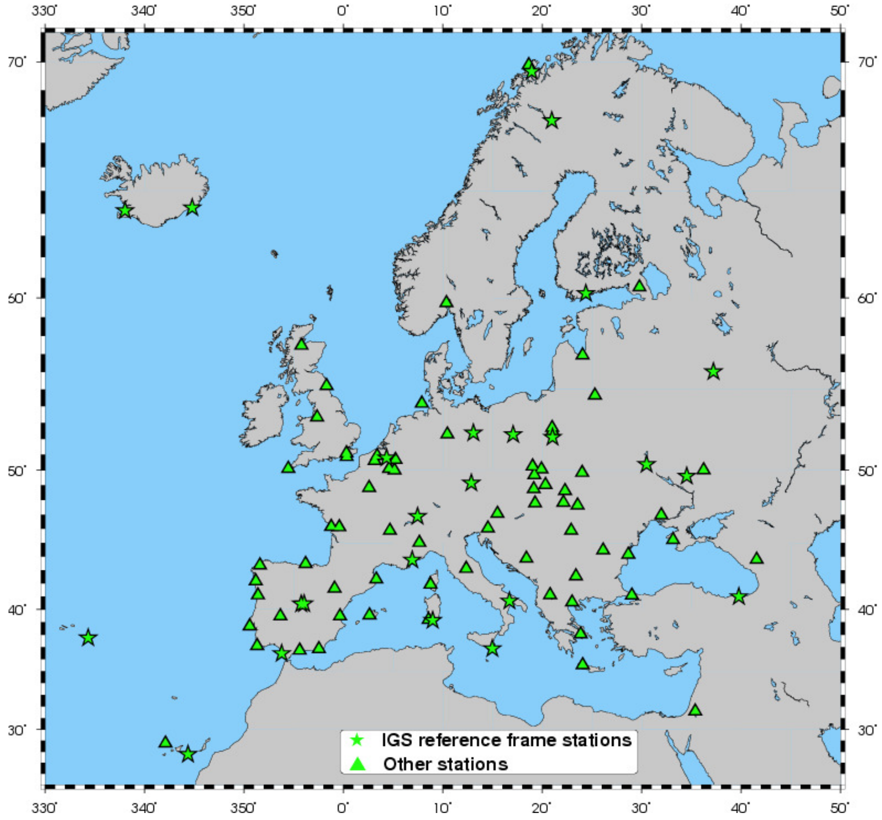

Figure 3 – EPN stations equipped with antenna/radome combinations with known true absolute PCV calibrations that were used in global solution

To obtain reliable results we processed the observation data for GPS weeks 1400–1407 (November 5 — December 30, 2006) from chosen stations (not all stations were active). The daily coordinates from the RPCVs were compared to the coordinates from the APCVs run using a Helmert transformation. The resulting coordinates can then be compared on a daily basis, or mean values can be formed.

Results

We computed a 7–parameter (variant *B3*) and a 1–parameter (only scale, variant *B3–SCA*) Helmert transformations between the each set of daily APCV and RPCV coordinates obtained for the regional network (*Khoda and Bruyninx, 2007*). In both cases the Helmert parameters were computed using IGS reference frame stations that were not rejected during each daily processing.

Also for the global network, the 7–parameter Helmert transformations between the sets of daily APCV and RPCV coordinates were computed using only the coordinates of the IGS reference frame stations that were not rejected during each daily analysis (variant *G3*).

As expected, the residuals of all Helmert transformations show that the height component is mostly effected by the change of the PCV model. Fig. 4 shows the means of the daily height residuals together with their formal errors (1 sigma) for the stations with the most popular antenna/radome combinations in the global network. Fig. 5 allows to compare the obtained mean values of the daily height residuals for the EPN stations for regional and global networks. In most cases the agreement between the height residuals obtained for the different stations with the same antenna/radome combination is at the 5–10 mm level.

For better comparison of the results obtained from the regional and global networks, the height residuals for some stations obtained for each of the three variants are presented in Fig. 6. It can be seen that for the "central" stations (BRUS, GRAZ, and WTZR) the height residuals from the regional solutions (variants *B3* and *B3–SCA)* are approximately equal and very close to the ones from the global solution (variant *G3)*. But for the stations that are on the ends of formed baselines (GLSV, MAS1, MDVJ, SVTL, TRO1, and ZECK) the height residuals from all variants are different.

We can say that the difference between the coordinates obtained when applying absolute or relative antenna phase center corrections depends on the geometry of the processed network (and consequently the reference frame definition) and the baselines that are formed and the correlation between the stations.

Table 2 shows the comparison of the mean values of the APCV – RPCV differences obtained from our regional (*B3*) and global (*G3*) daily solutions with the ones published by (*Ferland, 2006*). The agreement between our values and the ones from (*Ferland, 2006*) is poor. The reason for the poor agreement between our regional and global solutions is already mentioned above. The poor agreement between the values from our global solution (variant *G3*) and from (*Ferland, 2006*) can be explained as follows. The values in (*Ferland, 2006*) are the mean values from solutions of four IGS Analyses Centres (COD, EMR, GFZ, and MIT). All these centres used different software and different global networks to obtain their results. All these networks include not only stations with antenna/radome combinations with known true absolute calibrations. As a result the height differences for the same stations from these solutions differ on 5–15 mm level.

Table 3 contains mean values of the horizontal and height differences for all types of antenna/radome combinations with known true absolute calibrations from both our solutions, regional (variant *B3*) and global (variant *G3*).

Conclusions

The difference between the coordinates obtained when applying absolute or relative antenna phase center corrections depends on the geometry of the processed network and the reference frame defnition. Major differences are found when comparing the results obtained in a global network to the ones obtained in a regional network. We consider the results obtained in the global network as the most reliable.

It is clear that no universal value for the difference between the coordinates obtained with absolute and relative calibrations can be found. This is because the difference depends on the baselines that are formed and the correlation between the stations. Also different analysis strategies and different analysis software results influences the coordinate differences. And last, as already mentioned, the size of the network influences the differences.

We have also noticed that some of the antenna/radome pairs (e.g. LEICA504/LEIS) have very similar coordinate differences in the same geographical region. The question is posed if this effect is geographic or antenna specific.

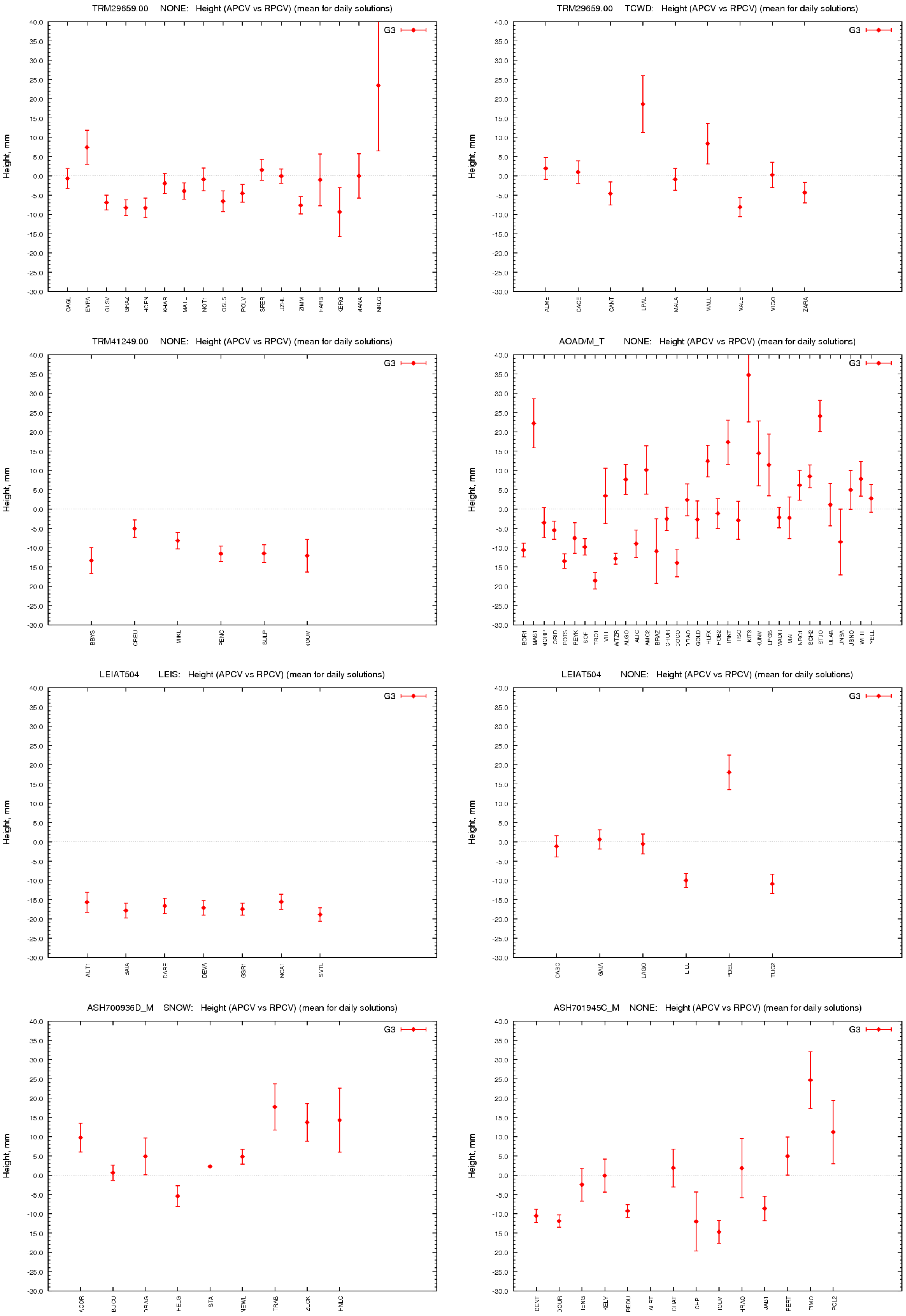

Figure 4 – Mean values of the height residuals of Helmert parameter determination (variant G3)

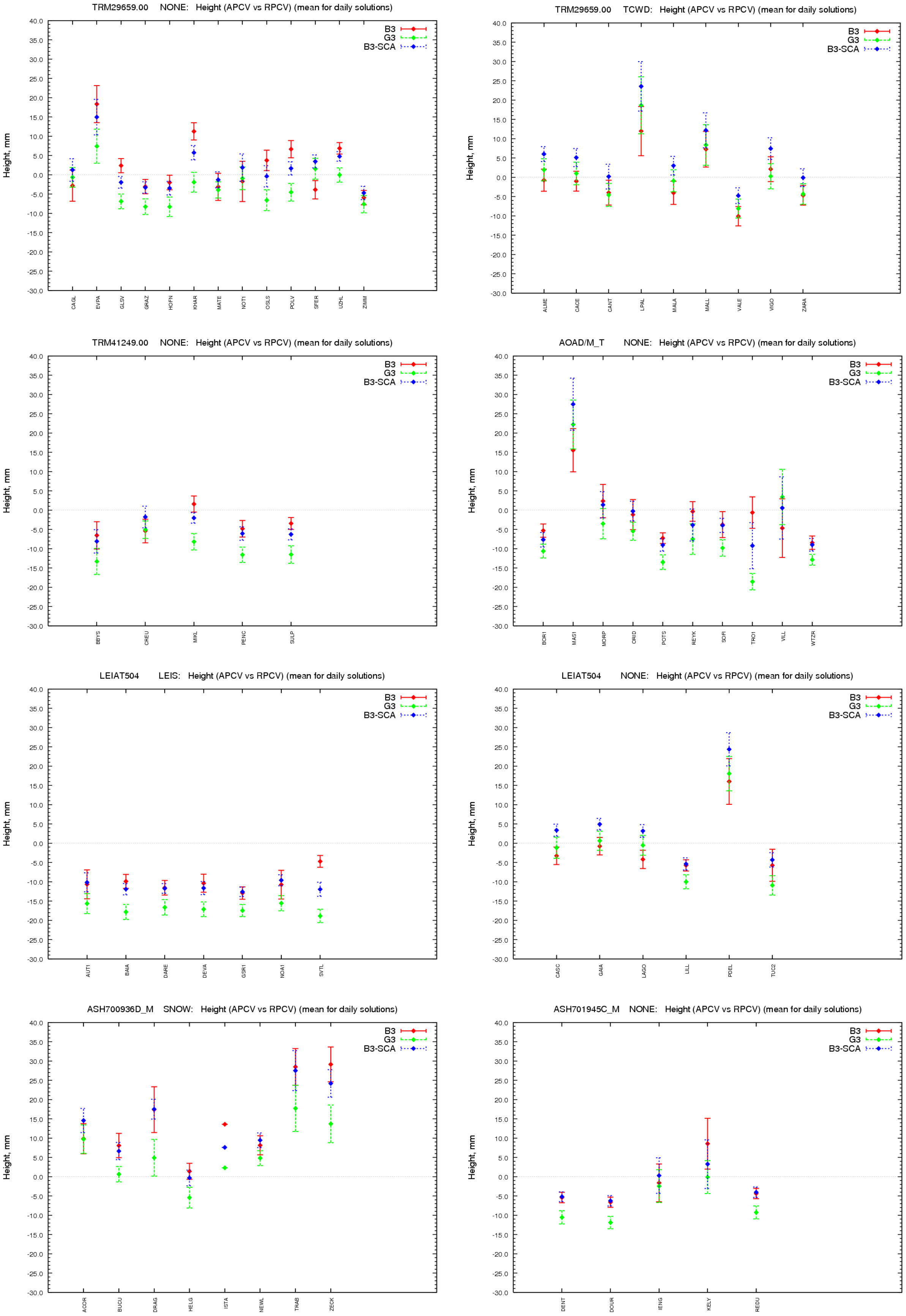

Figure 5 – Mean values of the height residuals for EPN stations for three different variants of Helmert parameter determination (variants B3, G3, and B3-SCA)

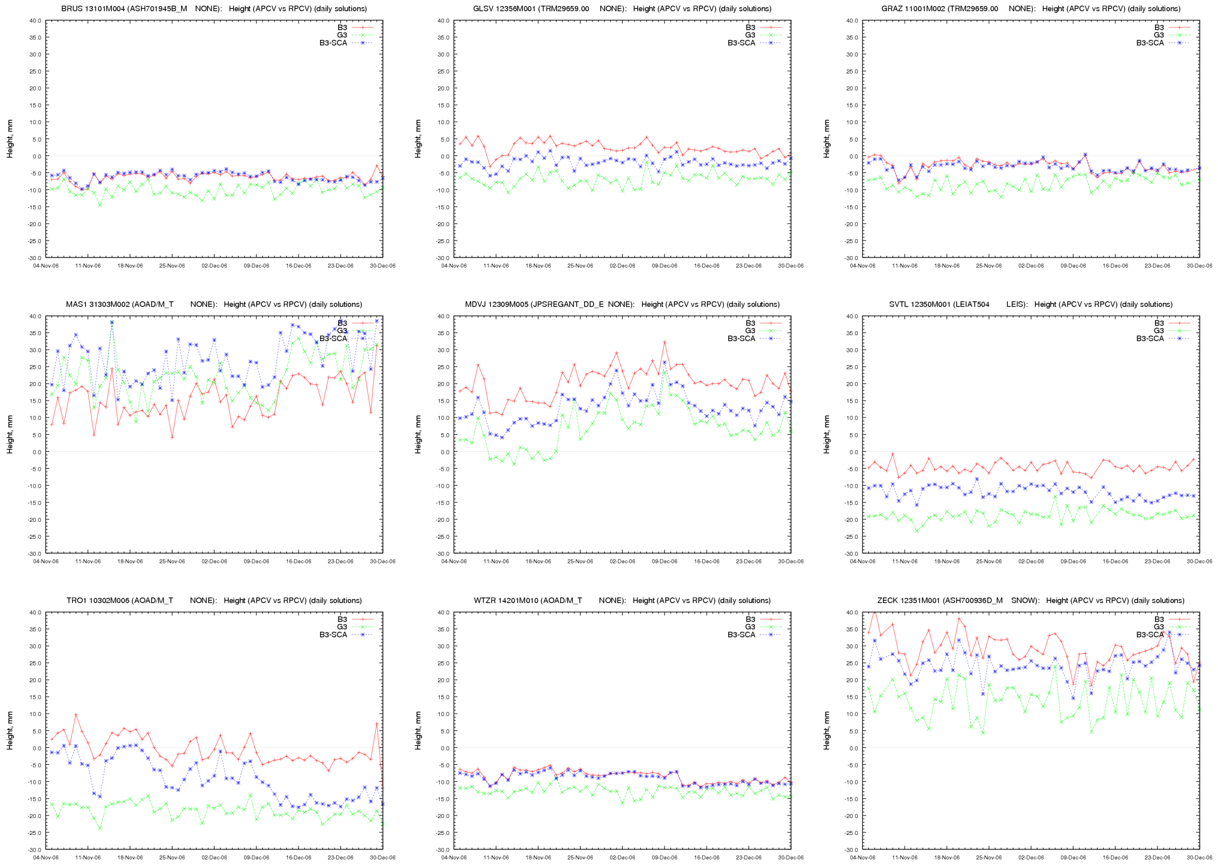

Figure 6 – Height residuals for EPN stations for three different variants of Helmert parameter determination (variants B3, G3, and B3-SCA)

Antenna	Dome	Station	Variant B3			Variant G3			(Ferland, 2006)		
			ΔN, mm	ΔE, mm	ΔH, mm	ΔN, mm	ΔE, mm	ΔH, mm	ΔN, mm	ΔE, mm	ΔH, mm
AOAD/M_B	NONE	METS	-1.50	-1.09	-1.00	0.24	0.48	-13.02	0.4	0.8	1.2
AOAD/M_T	NONE	BOR1	-0.81	-1.17	-5.30	-0.25	-0.24	-10.62	-0.4	0.4	4.6
		MAS1	1.97	-2.99	15.54	3.41	-0.41	22.21	-1.6	-2.1	7.9
		POTS	-1.05	-0.92	-7.26	-0.35	-0.15	-13.48	-0.2	0.8	0.9
		REYK	0.13	2.31	-0.34	0.16	-0.05	-7.51	0.1	-0.7	2.1
		TRO1	-4.79	-0.08	-0.62	-0.34	0.13	-18.54	0.5	0.4	-3.3
		VILL	-1.74	-2.47	-4.65	-1.64	-0.95	3.41	-0.8	-0.2	11.1
		WTZR	-0.49	-0.99	-8.44	0.01	-0.17	-12.86	-0.3	0.5	3.1
ASH700936D_M	SNOW	TRAB	4.56	-0.84	28.48	1.17	0.67	17.73	-0.8	0.9	16.6
ASH701945B_M	NONE	BRUS	-0.64	-0.57	-6.31	-0.04	-0.18	-10.06	0.0	0.3	3.6
ASH701945C_M	NONE	KELY	4.04	4.81	8.56	0.36	1.16	-0.11	-0.2	-0.5	0.6
ASH701945E_M	NONE	GRAS	-0.45	-1.04	-7.77	-0.02	-0.46	-8.65	-0.5	1.1	3.4
JPSREGANT_DD_E	NONE	MDVJ	3.64	-3.33	20.30	4.00	-0.42	6.93	4.1	-0.2	14.9
LEIAT504	NONE	PDEL	0.09	-1.14	16.02	-0.51	1.21	18.05	-1.2	-3.2	5.3
TRM14532.00	NONE	JOZE	-0.83	-0.28	-11.29	-0.36	1.05	-17.22	1.2	0.0	-4.9
TRM29659.00	NONE	CAGL	1.11	2.20	-2.81	1.83	2.76	-0.65	0.3	2.2	3.8
		GLSV	0.83	0.73	2.38	0.70	2.66	-6.90	0.2	3.0	5.1
		HOFN	0.08	3.99	-1.99	0.17	2.53	-8.30	0.8	0.5	3.3
		MATE	0.72	2.24	-3.13	0.69	2.95	-3.92	0.6	1.3	9.7
		NOT1	1.01	2.39	-1.70	1.05	2.81	-0.92	0.1	3.7	10.2

	POLV	1.47	0.40	6.65	0.95	2.73	-4.53	0.3	1.1	0.4
	SFER	1.93	1.69	-3.88	2.78	2.96	1.56	0.8	1.9	3.4
	ZIMM	0.47	2.02	-5.93	0.96	2.70	-7.62	0.7	2.8	2.0

Table 2 – Comparison of the mean values of APCV – RPCV differences for EPN stations

Acknowledgements

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References

Dach R., U. Hugentobler, P. Fridez, M. Meindl (Eds.) (2007). Bernese GPS Software Version 5.0. Astronomical Institute, University of Bern.

Ferland R. (2006). IGSMAIL-5447. http://igscb.jpl.nasa.gov/

Gendt G. (2006). IGSMAIL-5438. http://igscb.jpl.nasa.gov/

Khoda O., Bruyninx C. (2007). Switching from relative to absolute antenna phase center variations in a regional network: stability of the coordinate differences. Submitted to Proceedings of the Symposium of the IAG Subcommission for Europe (EUREF) held in London, England, 6–9 June 2007.

Antenna	Dome	N(mm) ± dN(mm)	E(mm) ± dE(mm)	U(mm) ± dU(mm)	Number of stations
AOAD/M_B	NONE	-1.50 ± 0.61	-1.09 ± 0.47	-1.00 ± 1.73	1 (*B3*)
		-0.30 ± 0.71	0.09 ± 0.78	-13.51 ± 2.88	2 (*G3*)
AOAD/M_T	NONE	-0.86 ± 1.63	-0.75 ± 1.55	-0.89 ± 7.51	14 (*B3*)
		0.10 ± 3.26	-0.82 ± 5.26	0.88 ± 11.92	35 (*G3*)
AOAD/M_TA_NGS	NONE	N/A	N/A	N/A	0 (*B3*)
		0.74 ± 1.51	2.29 ± 1.86	11.65 ± 4.27	1 (*G3*)
ASH700936A_M	NONE	-0.39 ± 0.90	-1.37 ± 0.68	1.14 ± 3.57	3 (*B3*)
		0.19 ± 1.11	-0.27 ± 1.34	-5.53 ± 4.20	3 (*G3*)
ASH700936B_M	SNOW	N/A	N/A	N/A	0 (*B3*)
		1.64 ± 2.77	-1.94 ± 2.73	9.87 ± 8.11	2 (*G3*)
ASH700936C_M	SNOW	-0.78 ± 4.05	1.16 ± 1.80	13.34 ± 3.96	1 (*B3*)
		-0.91 ± 5.99	0.78 ± 9.56	6.48 ± 8.66	3 (*G3*)
ASH700936D_M	NONE	0.10 ± 2.69	-0.24 ± 0.84	8.80 ± 5.94	1 (*B3*)
		-0.05 ± 2.88	0.11 ± 2.37	-2.64 ± 5.34	2 (*G3*)
ASH700936D_M	SNOW	1.55 ± 1.81	-0.88 ± 1.47	13.54 ± 10.39	8 (*B3*)
		0.47 ± 1.65	0.82 ± 2.84	6.84 ± 8.49	9 (*G3*)
ASH700936E	NONE	-0.97 ± 0.39	0.35 ± 0.65	-1.77 ± 1.81	1 (*B3*)
		-0.48 ± 0.63	0.74 ± 1.09	-5.19 ± 2.23	1 (*G3*)
ASH700936E	SNOW	-0.68 ± 1.04	0.89 ± 1.23	8.69 ± 3.74	2 (*B3*)
		0.02 ± 1.01	0.96 ± 1.23	2.37 ± 3.71	2 (*G3*)
ASH701073.3	NONE	-0.54 ± 0.40	-0.31 ± 0.50	-4.41 ± 1.81	1 (*B3*)
		0.56 ± 1.82	-0.56 ± 3.12	-6.47 ± 5.53	2 (*G3*)
ASH701945B_M	NONE	-0.62 ± 0.68	-0.92 ± 0.78	-2.59 ± 3.55	4 (*B3*)
		-0.16 ± 1.37	-1.07 ± 2.25	4.54 ± 5.37	5 (*G3*)
ASH701945C_M	NONE	0.17 ± 1.99	0.34 ± 2.50	-2.12 ± 6.49	5 (*B3*)
		-0.69 ± 3.36	-1.11 ± 5.52	-3.98 ± 14.07	14 (*G3*)
ASH701945C_M	SNOW	-1.16 ± 1.43	-1.98 ± 0.86	8.12 ± 3.19	5 (*B3*)
		-0.05 ± 0.71	-0.87 ± 1.19	-1.51 ± 3.75	5 (*G3*)
ASH701945E_M	NONE	-0.56 ± 0.38	-0.68 ± 0.56	-7.10 ± 1.97	2 (*B3*)
		-1.03 ± 4.19	-1.21 ± 4.47	-3.60 ± 11.05	4 (*G3*)
ASH701945G_M	NONE	N/A	N/A	N/A	0 (*B3*)
		0.10 ± 4.65	2.47 ± 6.78	6.37 ± 10.37	2 (*G3*)
ASH701946.2	NONE	-0.49 ± 0.40	-0.32 ± 0.68	0.14 ± 1.45	1 (*B3*)
		-0.01 ± 0.70	0.12 ± 1.09	-3.16 ± 1.60	1 (*G3*)
JPSREGANT_DD_E	NONE	3.48 ± 0.71	-2.20 ± 1.04	12.49 ± 7.08	3 (*B3*)
		3.91 ± 1.05	-0.74 ± 1.23	7.04 ± 4.60	3 (*G3*)
LEIAT504	LEIS	5.88 ± 0.72	0.49 ± 0.85	-10.68 ± 3.15	17 (*B3*)
		6.19 ± 0.78	1.36 ± 1.24	-17.01 ± 2.25	7 (*G3*)
LEIAT504	NONE	0.11 ± 0.98	-2.44 ± 0.84	-0.73 ± 8.20	6 (*B3*)
		0.24 ± 1.11	-1.35 ± 1.93	-0.71 ± 9.77	6 (*G3*)
TRM14532.00	NONE	-1.18 ± 0.81	-0.53 ± 0.50	-10.56 ± 1.92	2 (*B3*)
		0.15 ± 0.85	0.71 ± 1.10	-17.11 ± 1.86	2 (*G3*)
TRM22020.00+GP	NONE	2.50 ± 0.45	-1.20 ± 0.35	-7.00 ± 3.90	1 (*B3*)
		2.41 ± 0.75	-0.82 ± 1.78	-10.41 ± 5.20	1 (*G3*)
TRM29659.00	NONE	0.58 ± 0.78	1.68 ± 0.93	1.12 ± 5.72	36 (*B3*)
		1.06 ± 2.59	2.66 ± 3.41	-1.69 ± 9.13	17 (*G3*)
TRM29659.00	TCWD	1.43 ± 1.32	-0.57 ± 1.16	-0.23 ± 7.22	10 (*B3*)
		2.10 ± 1.63	0.46 ± 1.76	1.52 ± 8.58	9 (*G3*)
TRM41249.00	NONE	2.81 ± 0.63	-1.03 ± 0.69	-4.13 ± 3.78	6 (*B3*)
		2.44 ± 2.06	-0.55 ± 2.29	-10.45 ± 3.89	6 (*G3*)
TRM55971.00	NONE	2.45 ± 0.34	-0.09 ± 0.23	-15.39 ± 1.89	1 (*B3*)
		2.70 ± 0.58	1.02 ± 1.08	-22.99 ± 1.68	1 (*G3*)

Table 3 – Mean values of the residuals for variants B3 and G3