First Validation of new IGS Products Generated with Absolute Antenna Models

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Abstract

At its last workshop the IGS has decided to switch to the absolute receiver antenna calibrations, either obtained by robot field calibrations, anechoic chamber measurements or conversion from relative calibrations. After finalizing the compatible satellite antenna phase center variation model by TUM and GFZ using data from 1994 to 2005 a complete antenna model is available for testing. Since June 2005 (GPS week 1325) six Analysis Centers are contributing to a test with the new antenna model in parallel to the routine IGS Final products.
The parallel test has the goal (1) to test and validate the implementation of the new model in the various software packages, (2) to study the effects on the IGS products and (3) to generate a new compatible IGS Reference Frame.
The paper summarizes the results for the internal quality/consistency of the new products (satellite orbits, clocks, ERP) among the Analysis Centers and also the consistency to the 'classical' results. The new orbits and clocks were also tested in Precise Point positioning applications.

1 Introduction

The IGS will switch to the use of the new antenna model with absolute phase center variations (APCV) as soon as the ITRF2005 is published and its IGS realization (named IGS05) is generated and validated. It was decided to make only one transition together with both new models to avoid two bigger changes within a shorter time interval. Before the APCV can be introduced officially the related effects on all IGS products have to be checked carefully. Since June 2005 (GPS week 1325) the IGS Analysis Centers (AC) are generating Final products with the APCV model (igs05_1365.atx) in parallel to the routine Final products based on the relative antenna model (igs_01.atx). The only difference between both product lines is the antenna model used. The parallel run was set up (1) to test and validate the implementation of the new model in the various software packages, (2) to study the effects on the IGS products and (3) to generate a new compatible reference frame IGc00. Following ACs have contributed to the test:

COD (175), EMR (45), GFZ (185), MIT (145), NGS (145), SIO (170)
(in parenthesis the number of stations included in the solutions are given).

During the first weeks various bugs have been resolved with some reiteration. Since GPS week 1341 all ACs are in the final stage and therefore most statistics will start at that epoch. The products for the parallel Final run are internally named with the number '2' for the last character of the AC name (xx2), analogue, the combined results will be named IG2 and SNX2. If comparisons are performed with respect to the routine Final products those are named with IGF.

This paper will not touch the aspects of station coordinate and reference frame issues, those topics will be summarized by Ferland et al. (2006).

2 Comparison of orbits, clocks and Earth Rotation Parameters

In this section the parallel AC Final products, generated with the APCV model, are compared with the combined parallel IGS Final products (IG2), and in addition, the IG2 products are compared with the related products from the routine IGS Final combination (IGF). As supplementary information also the routine AC Final products are compared with the routine IGS Final combination (in the plots given by dashed lines or named by ROU).

The quality of the parallel AC Final orbit solutions, compared with the combined parallel IGS Final orbit solutions (weighted RMS over all satellites, Figure 1), is of the same level as the corresponding comparisons among the routine products (dashed lines). Only MIT benefits significantly from the new antenna model. Important is also that the new IG2 orbit solutions differ only 12 mm from the present routine IGS Final combined orbit solutions (IGF). Also the orbit scales for all the ACs is quite consistent between both product lines (Figure 2), and the scale of both combined orbit solutions is practically identical. The change of the GM value by -0.0003 km^3s^{-2} at GFZ, which results in a scale change of 0.25 ppb, can be seen in the statistics.

The Helmert translation parameters between all AC's and the IGS Final combined orbit solutions for both product lines are compared in Figure 3. Biases and standard deviations during the GPS weeks 1341 to 1359 are computed. For the AC's translation parameters a similar behavior can be seen between the APCV and the routine case. Both combined orbit origins agree by 1 mm, with a scatter smaller than ±2 mm (IGF). For the rotation the same high level of similarity can be stated. Both Final orbit solutions are only rotated by 0.05 mas, with a scatter smaller than ±0.03 mas (IGF).

Parallel and routine combined satellite clocks (no figure) agree by an RMS of 0.036 ns, which is the known noise level of that product. There is of course a clock offset between both products, which has a mean of 3.93 ns during the test weeks and is caused by the different – between absolute and relative antenna models – satellite antenna offsets in the order of 1.2 meter.

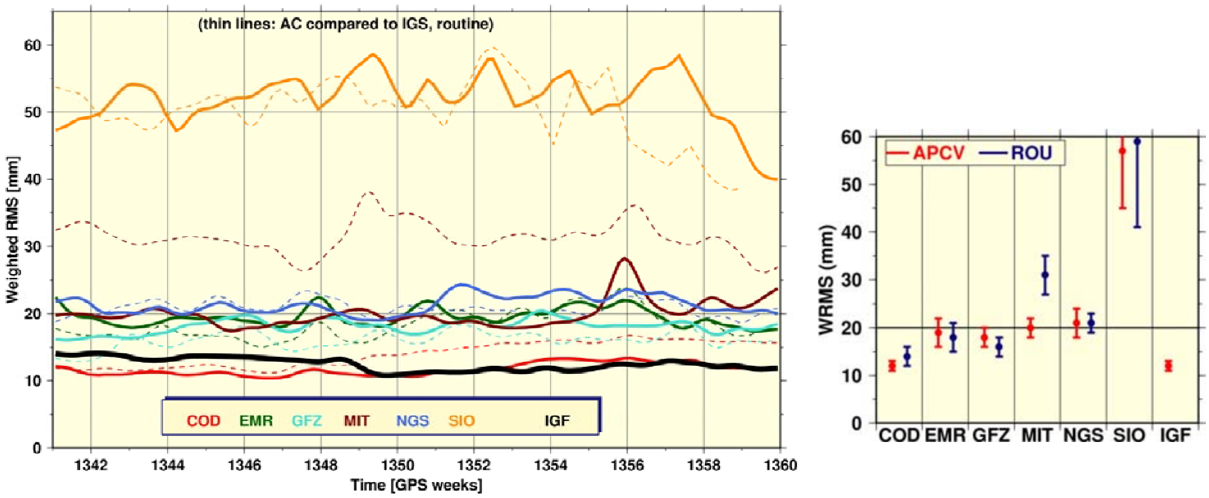

Figure 1. Differences (RMS over all satellites) of AC orbits from parallel Final test and routine Final combined orbits (IGF) with respect to combined orbits from the parallel test. For comparison, differences of routine AC Final orbits with respect to IGF are shown too (dashed lines) (left plot). For each series (APCV and ROU) mean and standard deviation to the corresponding combined products are given (right).

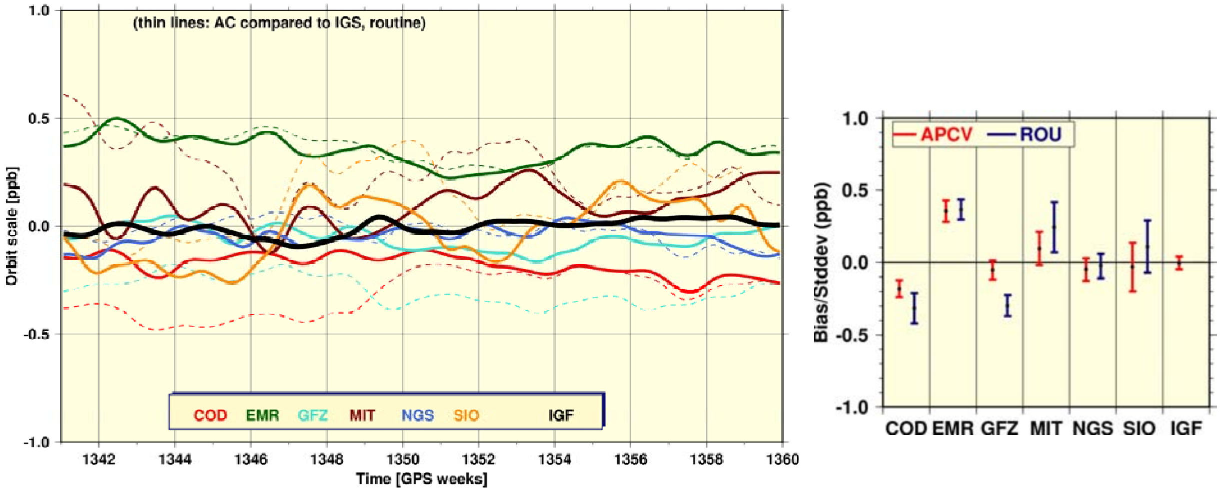

Figure 2. Scale differences of AC orbits from parallel Final test and routine Final combined orbits (IGF) with respect to combined orbits from the parallel tests. For comparison, scale differences of routine AC Final orbits with respect to IGF are shown too (dashed lines) (left plot). For each series mean and standard deviation are given (right).

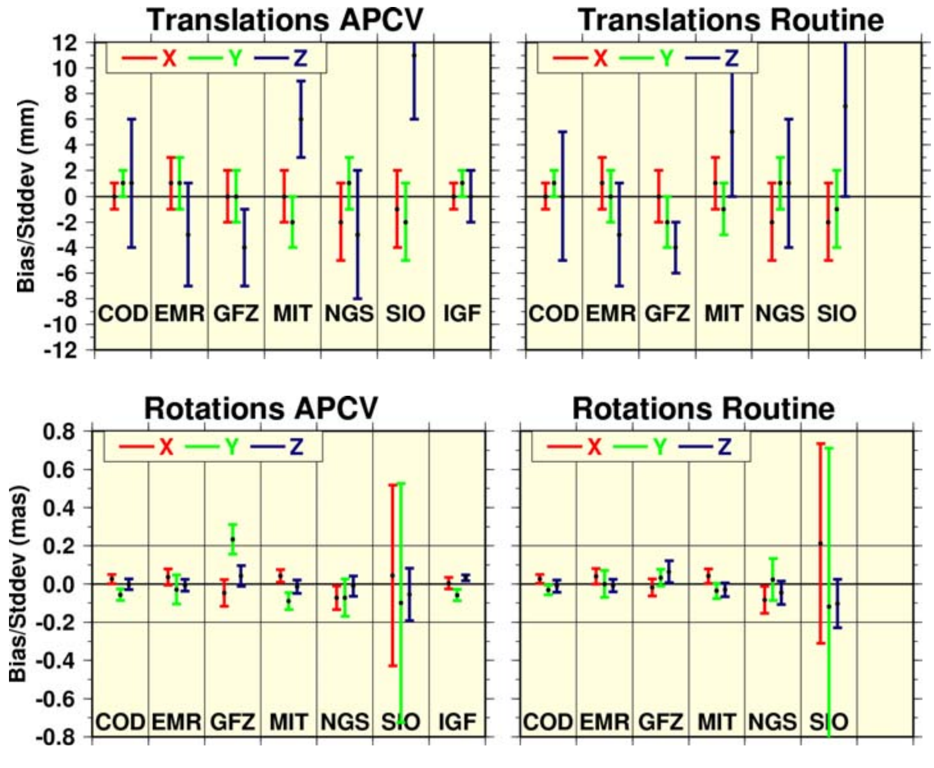

Figure 3. Transformation parameters of AC orbits from parallel Final test and routine Final combined orbits (IGF) with respect to combined orbits from the parallel tests (left two plots). For comparison, transformation parameters of routine AC Final orbits with respect to IGF are shown too (right two plots).

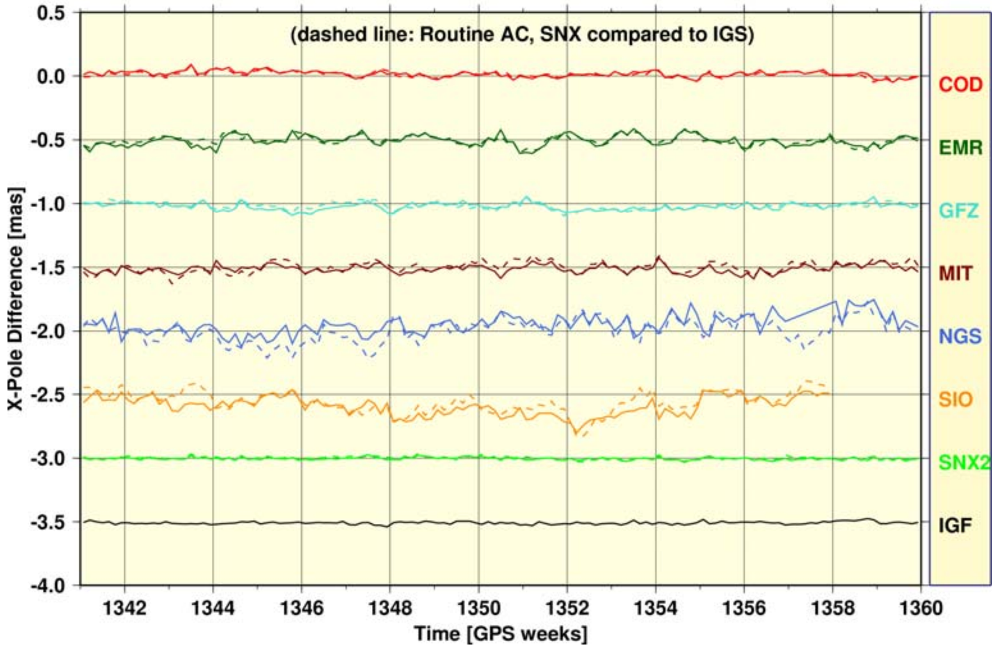

Figure 4. Differences of AC's x_p from parallel Final test, routine Final combined solution (IGF) and solution from parallel SINEX combination (SNX2) with respect to combined x_p from the parallel tests

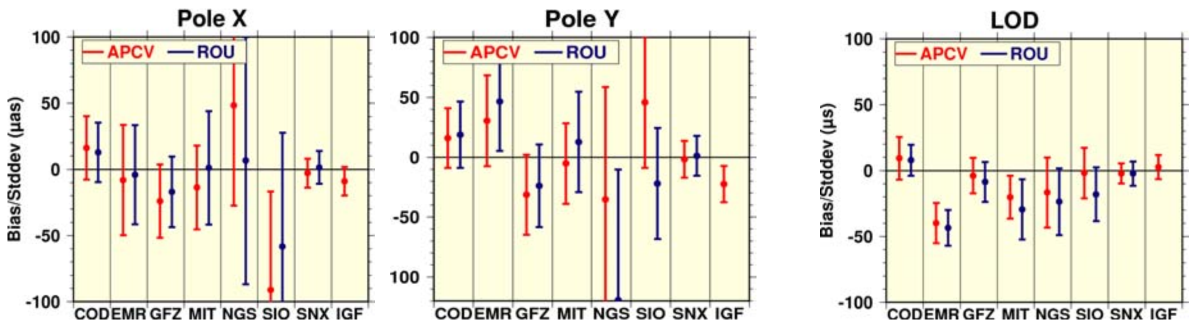

Figure 5. Statistics for differences of AC's ERP from parallel Final test, routine Final combined solution (IGF) and SINEX combination with respect to combined ERP from the parallel test (APCV). For comparison same differences of the routine ERP products are given (ROU).

IGS generates two Final series of the ERPs. Namely, one from the SINEX combination (igs00p02), which is the official IGS ERP series, as well as an independently, directly combined one (igs95p02), which is using the same weights as in the orbit combination. Both products also generated in the parallel test.

All ERP series are compared to the directly combined ERP files from the parallel AC Final products. As an example, the time series of differences for x_p are shown in Figure 4. The high quality of the AC estimates, and also the nice agreement between the behavior of the new and the routine results, can easily be seen. The agreement with the parallel SINEX combined ERP (SNX2) and with the routine IGS Final combined ERP (IGF, igs95p02) is excellent. The statistics for x_p, y_p and LOD (Figure 5) confirm the same high quality, as known from the routine, of the AC results for the parallel test. The consistency to the SNX2 ERP series is very high, with standard deviations for the three components of ±10 µas, ±15 µas and ±7 µs and with no significant bias, and is at the same level as the agreement within the routine products. The differences with respect to the directly combined routine Final ERPs (IGF) is at a similar level, with a small bias in y_p, which should not be considered as critical having different numbers of ACs contributing to the parallel Final tests and to the routine products.

3 Validation of PPP products

The Precise Point Positioning (PPP) is an important tool, applied by many users, and therefore the performance of PPP products based on the parallel Final products have to be validated carefully too.

Orbit and clock solutions of those ACs, which are providing estimated clocks with 5-min sampling rate, and of the IGS Final combined products are used to generate PPP results during GPS weeks 1341 to 1359. All stations defining the reference fame IGb00 are included, about 90 each week. Helmert transformations to the combined weekly SINEX solutions – scale, translations and residual station coordinates in north, east and up (rms over all the stations in the network) – are used in the validation.

The consistency and quality of all PPP results from the parallel Final products (Figure 6) is at a level known from the routine IGS products. This can easily be seen, if one compares both combined solutions, the new and the routine one, with the corresponding weekly SINEX combinations (Figure 7). The visible differences between both curves are at the noise level, with the only exception of the scale. The scale of the parallel Final products is near zero, because the antenna offsets were determined with the condition to provide the ITRF scale for 2000.0. The small scale differences still seen are on the one hand caused by the scale rate error in the IGb00 of about 0.15 ppb/y and on the other hand by the fact that for the generation of the satellite antenna model only two solutions (TUM and GFZ) were combined and that six AC solutions, which have all its ‘own’ scale bias (see Gendt and Kouba, 2006), entered into the IG2 products.

A special test was performed, where not the full new APCV model has been used. It was assumed that a user has an old software capable of applying satellite antenna offsets and receiver elevation dependent PCVs only, i.e. ignoring the satellite antenna nadir dependence and the azimuthal dependence for the receivers. Comparisons with respect to the products obtained with the full model (Figure 8) show only translation effects smaller than half a mm, scale changes of 0.8 ppb and mean biases in the station positions, which, as expected, amount to 2 mm in the height component and sub-mm in the north and east components. The position biases are, of course, site dependent. In Figure 9 the effects are plotted for all stations. In addition to the mean scale change, a scatter of ±5 mm in the heights can be seen, where the arrangement per antenna shows that the differences are not only caused by the antenna model alone but influenced by the station environment too. The effect of the azimuthal receiver PCV patterns only was also tested by running two PPPs – one with the full PCV model and one with the elevation means (Figure 9, bottom). For the north and east components the effects are smaller than 0.2 mm (not shown) and for the heights they are in most cases within ±1 mm. From this results one has to conclude that it is most important to apply the new satellite nadir dependence, its effect is much larger than that of the azimuthal PCVs.

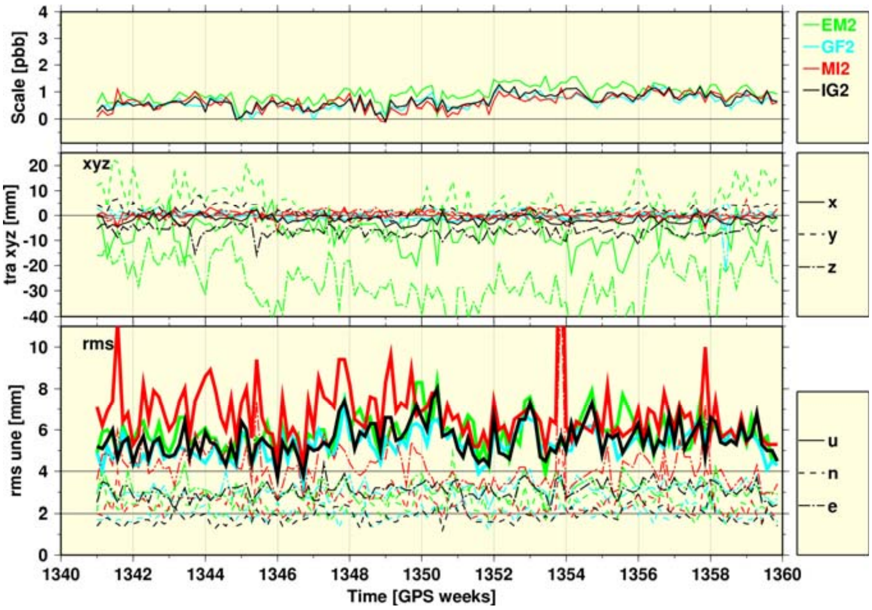

Figure 6. Helmert transformation results (scale, translation, rms of station residuals in N, E, Up) between PPP solutions and weekly IGS SINEX combination. All results are from the parallel Final test. Orbits and clocks from three ACs (EM2, GF2, MI2) and from the combined product (IG2) are used.

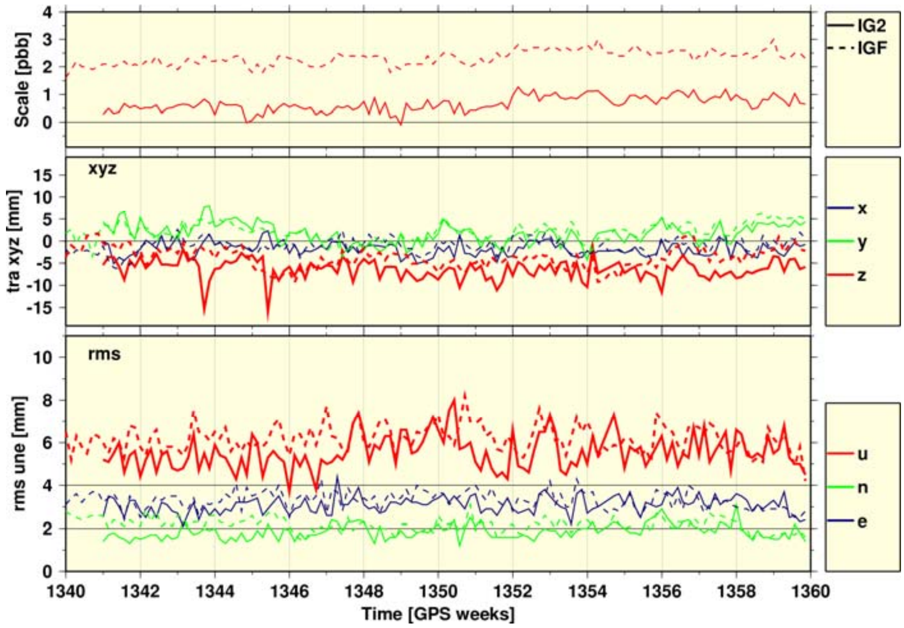

Figure 7 . Helmert transformation results (scale, translation, rms of station residuals in N, E, Up) between PPP solutions and weekly IGS SINEX combination. Orbits and clocks from combined parallel Final products (IG2) and from routine Final products (IGF) are used. Both are transformed with respect to the corresponding weekly IGS SINEX combination.

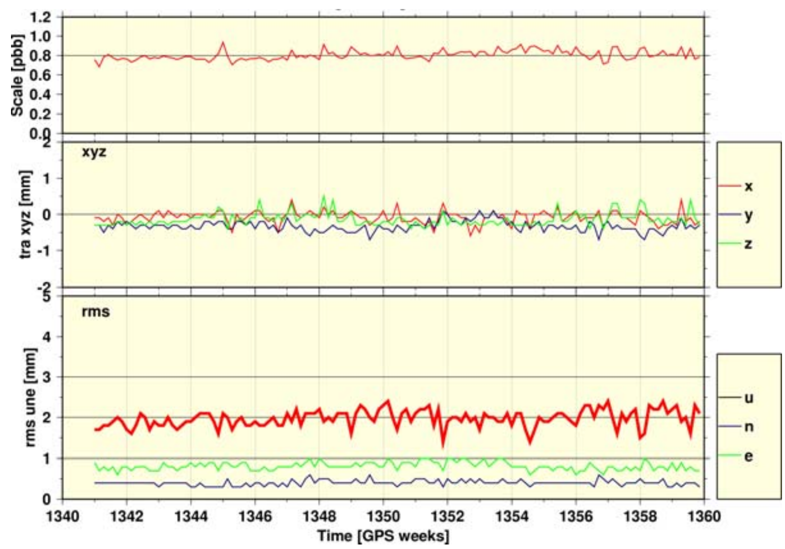

Figure 8. Helmert transformation results (scale, translation, rms of station residuals in N, E, Up) between PPP solutions and weekly IGS SINEX combination. Orbits and clocks from combined parallel Final products (IG2) are used within a software, which has ignored satellite antenna PCVs and azimuthal receiver PCVs.

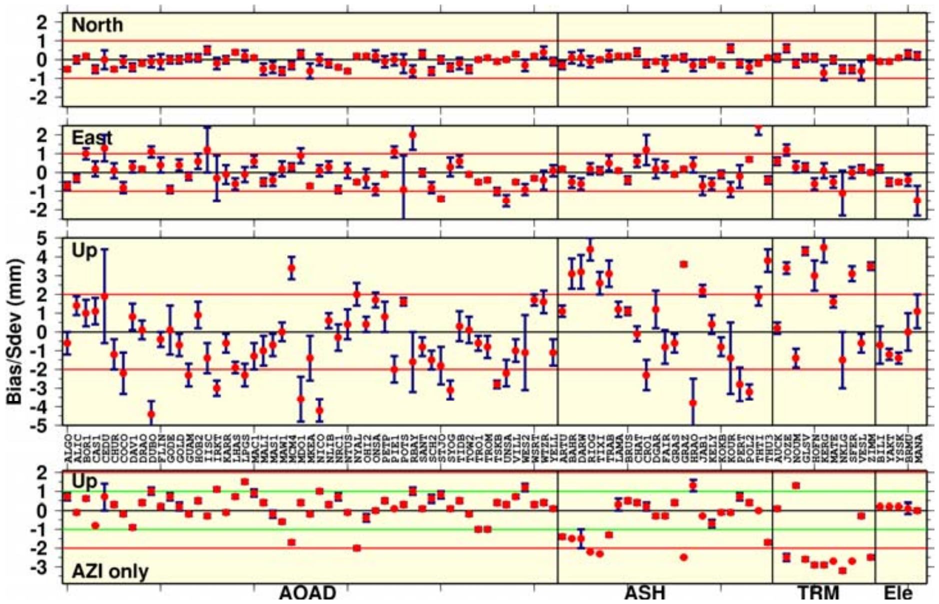

Figure 9. Mean and standard deviation of PPP station residuals (method see Figure 8). Stations are sorted per antenna model (Ele are antennas with only elevation dependent PCVs). The overall scale change of ~0.8 ppb is already subtracted from Up. The differences between solutions using PPP with and without azimuthal PCVs are shown in the bottom plot (N and E < 0.2 mm).

4 Troposphere estimates

The differences in the total zenith path delay (ZPD) estimates, generated using the absolute and the relative PCV models, should be checked too. For that purpose, ZPD products from GFZ network solutions were taken. For the GPS weeks 1368 and 1369 hourly ZPD estimates for ~190 stations from both products lines are compared. The differences between the time series for the individual stations – bias and standard deviation – are shown in Figure 10. The mean bias of about -6 mm will nearly compensate the GPS wet bias seen in many comparisons to VLBI, water vapor radiometers and radiosondes, so that the new products should be more valuable for the GPS meteorology.

5 Summary

The tests with the absolute antenna PCV model have shown a high quality of the new results and verified the readiness of the IGS ACs to switch to the new APCV model. There are no significant biases with respect to the old products for scale, translation and rotation in the orbit solutions. The differences between the ERPs are at the noise level, with 0.015 mas in the pole position and 0.010 ms in LOD. The PPP technique delivers results with the same quality as known for present products, and the scale is even closer to ITRF.

6 References

Ferland, R., M. Bourassa (2006): From relative to absolute phase center calibrations: The effect on the SINEX products. *this volume*.

Gendt, G. and J. Kouba (2006): Quality and consistency of the IGS combined products. *this volume.*

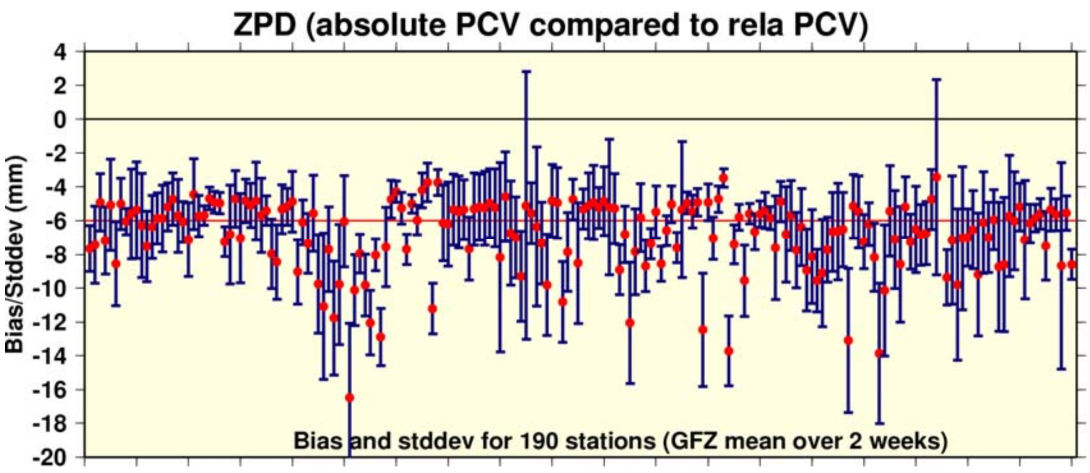

Figure 10. Total zenith path delay estimates of GFZ for 190 stations during GPS weeks 1368 and 1369. Differences (bias and standard deviation) of hourly estimates between the parallel (APCV) and the routine (relative PCV) Final results are plotted.