EUREF Permanent GPS Network Analysis Update

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Abstract

In 2001 the 3rd Local Analysis Center (LAC) Workshop took place in Warsaw, Poland. It was settled at that workshop to change some processing options with the beginning of GPS week 1130 to improve the EPN products. The LAC's solutions are fixed to the current ITRF since the same week in order to support the EPN Troposphere Special Project, and a coordinate re-substitution is applied in the final estimation of the hourly troposphere parameters. The ITRF2000 reference frame is used in the EPN analysis since week 1143 according to the changes within the International GPS Service (IGS). There is an initiative within the IGS to establish a densification of the global IGS network by, e.g., regional networks. This approach requires the correct alignment of the regional networks to the global one. Two EPN test solutions are generated for that purpose.

Introduction

There are currently 15 LACs which each of them analyses a sub-network of the EPN. The LACs submit weekly SINEX files of station coordinate solutions and daily SINEX files of station troposphere parameter solutions to the EUREF Data Center at the Bundesamt für Kartographie und Geodäsie (BKG). This report deals with the analysis method and the coordinate results. A detailed report about the troposphere parameter combination is given by the Troposphere Coordinator at the 2002 EUREF symposium. There is an agreement to use common processing options by all LACs in the analysis of the EPN observations. These options will be changed to new selections or models if obviously the results will improve. Changes of the processing options have simultaneously to be introduced by all LACs to identify the corresponding changes in the results. Such changes took place in the year 2001 and are outlined in the next paragraph.

Table 1: EPN Processing History 2001/2002

16 – 19 May 2001	– EUREF 2001 Symposium, Dubrovnik, Croatia
31 May – 01 June 2001	– 3rd Local Analysis Center Workshop, Warsaw, Poland
2 Sep 2001 (week 1130)	– Introduction of new processing options, following the minutes of the 3rd LAC Workshop, Warsaw – SINEX files submitted by the LACs are fixed to the ITRFxx (contribution to Troposphere Special Project) – New analysis center IGE introduced into the combined solution
14 Oct 2001 (week 1136)	– New product generation for test purposes: Densification of global IGS weekly solution, product not official and not public available – New product generation: Transformation of the EUREF fixed solution from ITRF into ETRF, product not official and not public available
November 2001	– Proceedings of the 3rd Local Analysis Center Workshop published in the Reports on Geodesy No3 (58), 2001, Warsaw University of Technology
2 Dec 2001 (week 1143)	– Change from ITRF97 to ITRF2000 in reference frame realization – New analysis center SGO introduced into the combined solution
9 Dec 2001 (week 1144)	– Comment lines in the SINEX file header as submitted by the LACs are extracted and distributed to the LACs
12 Jan 2002 (week 1149)	– New product generation for test purposes: Densification of global IGS cumulative solution, product not official and not public available
5 – 8 June 2002	– EUREF 2002 Symposium, Ponta Delgada, Portugal

EPN Processing Changes

All remarkable changes since the EUREF 2001 symposium concerning the analysis of the EPN observation data are summarized in Table 1. A very fruitful LAC Workshop had been hold at the Warsaw University of Technology in May/June 2001. Representatives of the LACs reported about their activities and the status of the EPN Special Projects had been presented too. Details about that workshop may be found in the proceedings [SLEDZINSKI, 2001]. It was

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agreed upon to commonly change some processing options in the EPN analysis with the beginning of GPS-week 1130. These new options are given in the minutes of the LAC workshop which are available on the web-page of the EPN Central Bureau [BRUYNINX, 2002] and summarized in Table 2. The observation elevation cut-off angle was lowered to 10/ in order to better de-correlate the station height and troposphere parameters, and the elevation dependent weighting of observations was introduced, to account for the increased noise of observations on low elevations. The LACs now use the Niell mapping function to more realistically map the tropospheric delay into zenith direction. Figure 1 shows the RMS of the Helmert residuals, which result from weekly Helmert transformations between each LAC solution and the combined solution. The numbers in the plot are mean RMS values averaged over all stations and all LACs. A significant reduction of the RMS of the height component after the introduction of the new options becomes visible in the plot. It confirms that the height consistency between the individual LAC solutions has improved.

Table 2: Summarized minutes of the 3rd LAC Workshop in Warsaw, May/June 2001

Guidelines	Recommendations
– Usage of IGS Orbits – Introduction of Ocean Loading Corrections – 10/ elevation cut off angle and elevation dependent weighting of observations – Usage of Niell mapping function for troposphere parameters	– Estimation of hourly troposphere parameters – Save troposphere parameters in daily normal equation files, generate weekly SNX solution, re-generate TRP files with fixing on SNX coordinates – Ambiguity fixing – Include RMS of unit weight in SNX files (Bernese Software only)

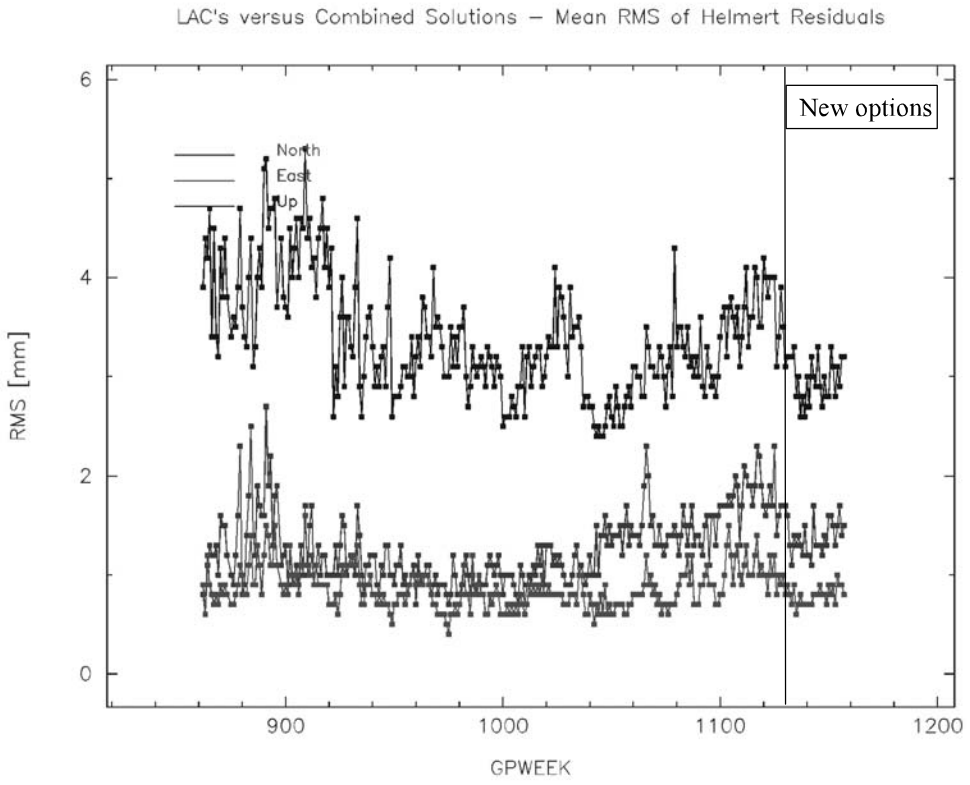

Figure 1: Helmert transformation between Local Analysis Center solutions and combined solution

Improvement of ZTD Parameters

The recommendations of Table 2 are mandatory for those LACs which contribute to the Troposphere Special Project. A so-called 'coordinate re-substitution' is performed by the LACs since week 1130. The LACs heavily constrain their weekly coordinate results in the final estimation of the troposphere parameters for the daily troposphere files. It yields a consistency of station coordinates and troposphere parameters of the weekly solutions of each LAC. All coordinate constraints will be removed before the combination of the LACs SINEX files and have no effect on the combined coordinate product at all. The motivation for this procedure is to reduce the biases in the combination of the station

specific troposphere parameters. These biases are calculated by the EUREF Troposphere Coordinator and are given in the weekly summary files EURwwww7.TSU, where 'wwww' means the gps-week.

Additionally the LAC solutions are aligned to the ITRF since week 1130. This reference frame alignment will again contribute to a reduction of the troposphere biases, because it improves the consistency between the individual LACs. By the alignment of all EPN sub-networks to ITRF approximately identical station coordinates are hold fixed in the troposphere parameter estimation. A full consistency of station coordinates and troposphere parameters could be achieved, if identical coordinates, e.g., the coordinates of the final combined solution, would be hold fixed during the troposphere parameter estimation. But this is currently not realized. Figure 2 shows weekly coordinate variations for the BKG solutions, which have been calculated as follows: For each station the coordinate difference between a) the coordinates as given in the submitted SINEX file of the specified LAC and b) the coordinates of the combined solution is calculated. It is assumed, that weekly variations caused by the datum definition are identical for all stations and the plot shows only the mean value of the differences after applying a majority voting. Following this assumption the variations of the mean coordintate differences may be interpreted as variations of the reference frame. The week to week variations disappear since week 1130, after BKG started to submit solutions aligned to the ITRF.

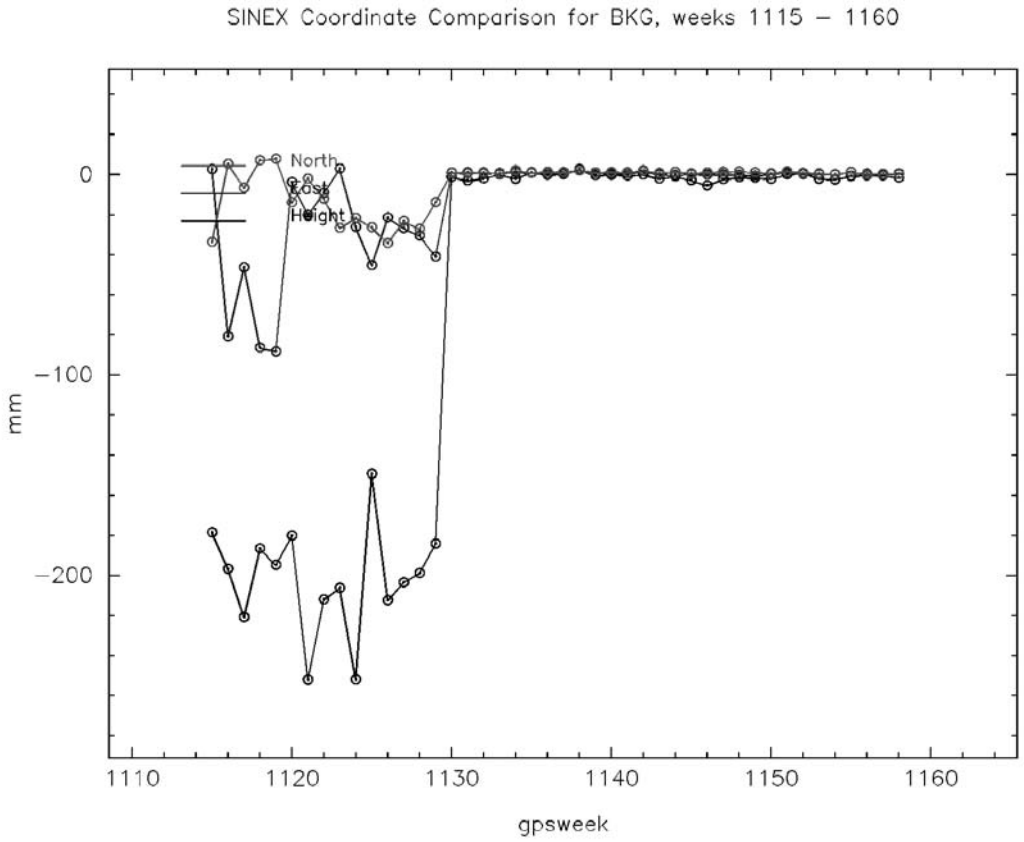

Figure 2: Coordinate variations in BKG SINEX files

In order to study the effect of the station height variations on the troposphere bias variations both parameters are shown in Figure 3. Typically these parameters are highly correlated. The black line shows exactly the same height variations as given in Figure 2. The 'original' troposphere biases for BKG solutions, as calculated by the Troposphere Coordinator, is given in the grey line. Now we consider the a change of 1 mm in the zenith tropospheric delay parameter may change the station height of 2 to 6 mm [BOCK et al., 2000]. But no correlation becomes visible if we compare the grey and the black lines. Furthermore the scaling of the troposphere biases with a factor of 2 to 6 ,following the relations mentioned above, will not show the expected high correlation for the period before week 1130. However if the troposphere biases are scaled with the empirical determined factor 50, as is given in the red line in Figure 3, we see nearly identical variations of the scaled troposphere bias and the stations heights. It confirms the high correlation between both parameters, but the factor of 2 to 6 as given in the reference paper, may not be correct for large height variations. For the period after week 1130 the empirical determined factor 50 is not correct.

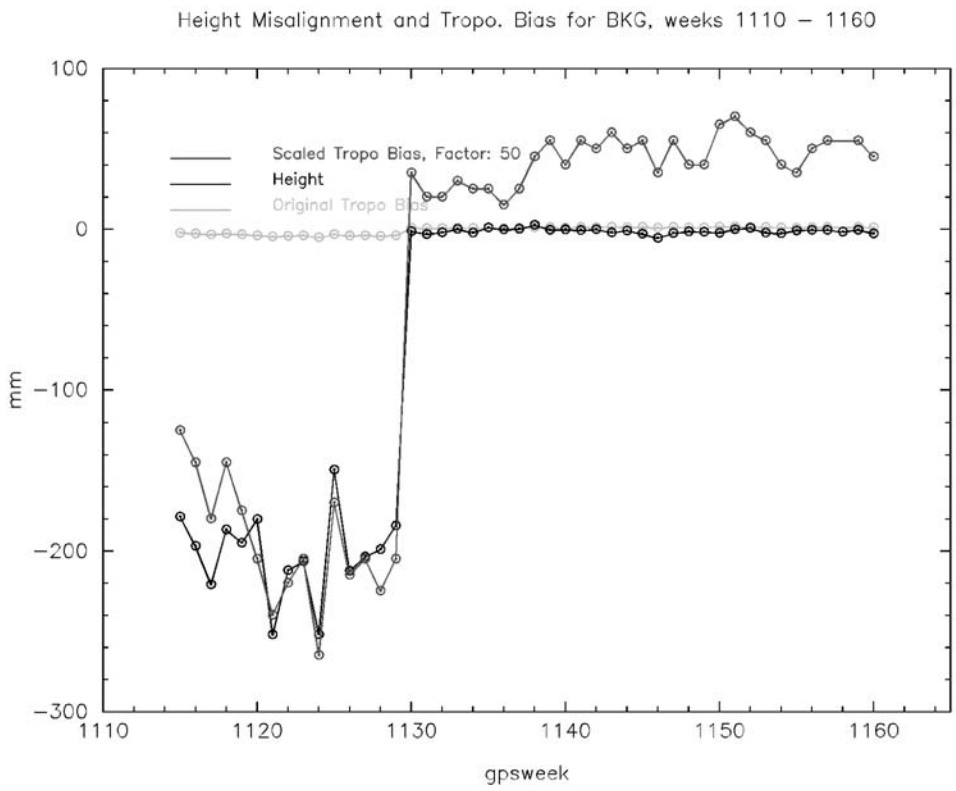

Figure 3: Station height and troposphere bias variation

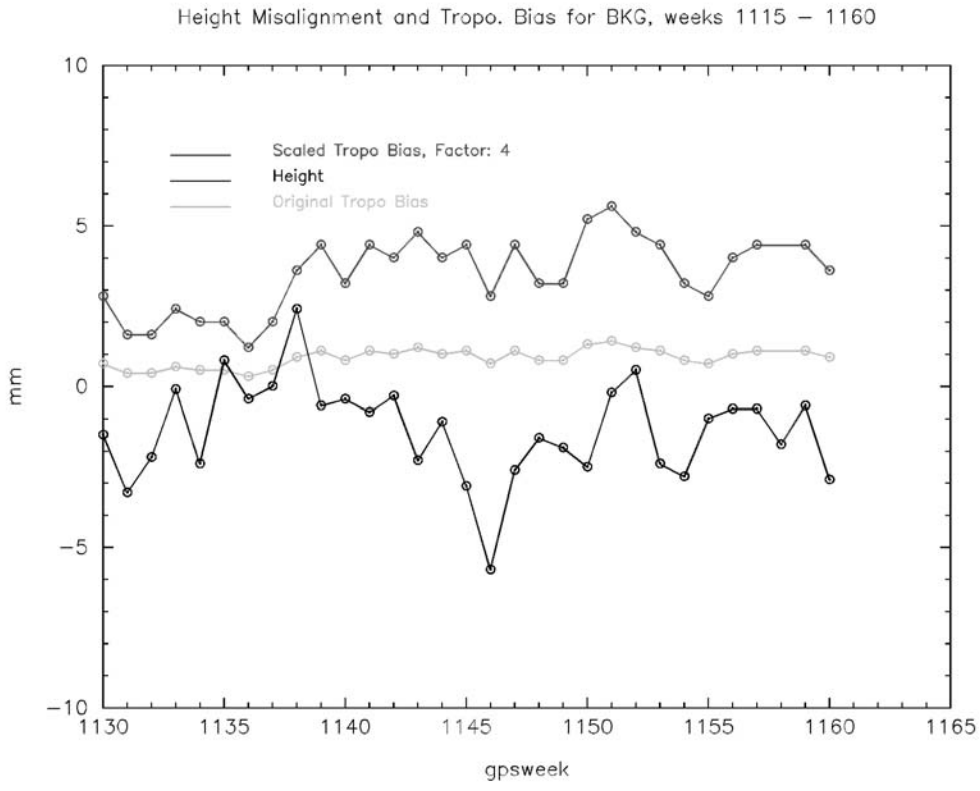

Figure 4: Station height and troposphere bias variations after reference frame alignment

Figure 4 shows a special focus on the period after week 1130. A scaling factor of 4 has been empirically determined to verify the between troposphere bias and station height correlation. It fits now the numbers as given in the reference paper. Some outstanding weeks may be explained by the different outlier detection, which had been applied in the independently calculation of the two parameters. We conclude from Figure 3 and Figure 4, that the correct scaling factor between the two studied parameters depends on the absolute range of the height variations. The same behavior has been verified in tests for all other LACs.

It has to be mentioned, that the mean station height variations, which are shown in Figures 3 and 4, may only be considered as a 'trend' and a detailed study of each single station is necessary. The systematic variations of the biases may be reduced, if the final combined EPN coodinate results (official weekly EPN products) would be used for the coordinate re-substitution. The Troposphere Coordinator will ask the LACs to compute such solutions for test purposes.

Change from ITRF97 to ITRF2000

All LACs use the ITRF2000 since week 1143 (the week when IGS switched from ITRF97 to ITRF2000) to be consistent to the IGS and to take benefit from the improved reference frame. The red curve of Figure 5 shows the RMS of the residuals of Helmert transformations between ITRF97/2000 and the EUREF combined solutions, which are heavily constraint to ITRF97/2000 through 12 reference sites. The weekly EPN solutions fit better to the ITRF since week 1143, because new observations, which are closer to the current epoch, had been introduced into the ITRF2000 calculations. Since week 1153 Helmert transformations between the ITRF2000 and the EPN free-network solutions are calculated as well and the corresponding RMS values are given in the blue line. The 12 reference sites, which are used to formulate the free network conditions for the datum definition in the free-network solutions, are identical to those used to constrain the fixed solution. The equivalence of the red and the blue lines confirms, that the alignment of the EPN to the ITRF is equivalent for the fixed and the free solutions (see also presentation by Z. ALTAMIMI at EUREF 2002 Symposium).

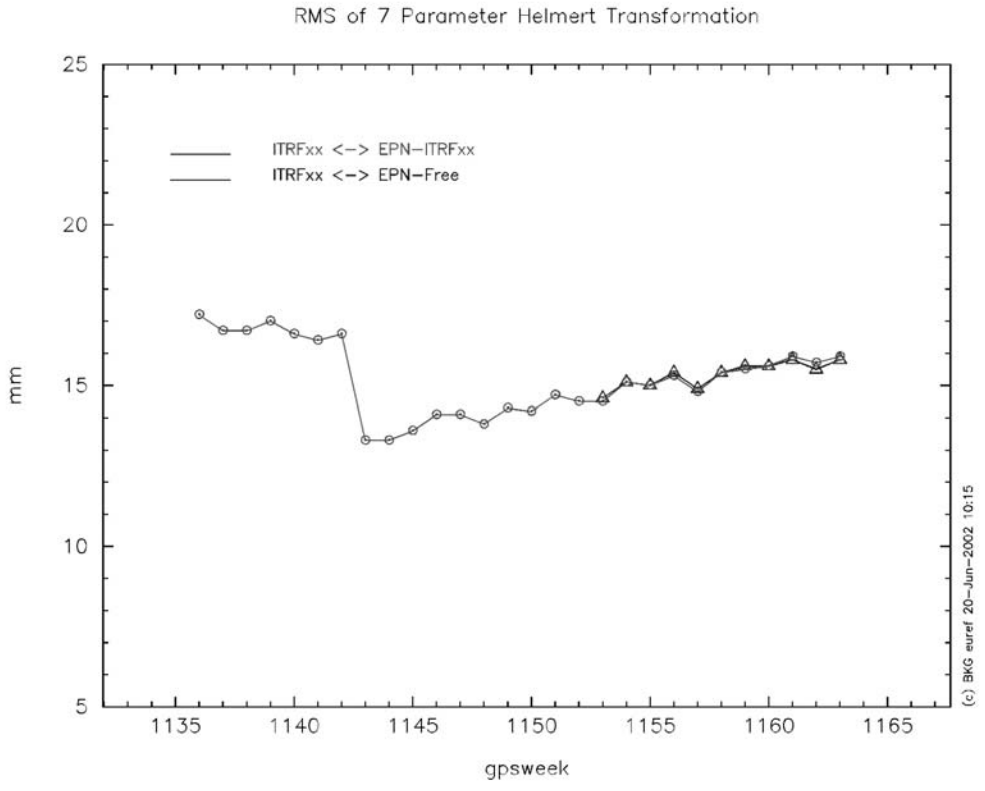

Figure 5: Helmert transformation between weekly EPN solutions and ITRF

EPN Reference Frame Alignment

An initiative started by the IGS aims to realize a dense global GPS network, which is fully consistent to the IGS products (satellite orbits, earth orientation parameters, reference frame, …). One candidate concept for densification of the existing global IGS network consists of the alignment of regional GPS networks, such as the EPN, to the global IGS solution. This concept was also topic of the IGS 2002 Workshop in Ottawa, Canada, in April 2002. Three different methods had been presented at the workshop in order to align a regional network to a global one. Zuheir Altamimi presented the theory and results of the formulation of free-network condi-

tions to align a network solution. MIKE CRAYMER and REMI FERLAND reported about the usage of Helmert Transformations for network alignment. Heinz Habrich showed results after constraining the common sites of the global and regional solutions to define the datum of the regional solution. The IGS Reference Frame Coordinator will now compare the results of these three methods.

The EPN currently holds about 122 stations in and around Europe. As 42 of these stations are included in the IGS global network, the remaining 80 stations may be considered to be a regional densification of the IGS reference frame. For that purpose two test solutions of the EPN are generated by the EPN Analysis Coordinator on weekly basis (see Table 1). The first solution aligns the weekly EPN solution to the weekly IGS solution; the second one aligns a newly generated cumulative EPN solution to the cumulative IGS solution. The IGS coordinates of the common stations are fixed in both solutions. It is planned to continue the generation of these test solutions to study the quantity of the differences to the current official products until a final decision about the densification method has been made by the IGS. The continuously generation of the current official products will be guaranteed in any case.

Conclusions

As shown in this report the EPN has implemented state of the art processing options and will go on in the future to realize the highest level of accuracy. The close cooperation between IGS and EUREF, which is currently held by the regional densification activities, provides benefit for IGS from EUREF and vice versa. The EPN products are the achievement of the continuous effort of the station operations, data centers and analysis centers among others.

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