EUREF Symposium in London, UK, 6 – 9 June 2007

Updated Options and New Products of EPN Analysis

H. Habrich

EPN Analysis Coordinator
Federal Agency for Cartography and Geodesy, Frankfurt, Germany

Abstract

The introduction of absolute phase centre variations (PCVs) for satellite and receiver antennae within the analysis of the International GNSS Service (IGS) with the beginning of GPS week 1400 in November 2006 changed significantly the IGS products. The EPN analysis refers to IGS products, as satellite orbits and reference station coordinates, and has thus to update the analysis options too. Special arrangements had to be found for those EPN stations, which operate antennae not included in the IGS list of PCV numbers, a file in the ANTEX format. At the same time the EPN introduced the new ITRF2005 realization of the terrestrial reference frame and new transformation parameters from ITRF2005 to ETRF2005 must be applied. A critical aspect is the alignment of EPN coordinate solutions, which are derived in the today analysis process using absolute PCVs, to the ITRF2005, which is based on relative PCVs. Both coordinate solutions show mainly station specific differences in the height component. The alignment to ITRF2005 is needed to transform from ITRF2005 into ETRF2005. Numerical results concerning coordinate changes will be summarized. A new multiyear solution for all EPN stations and consistent with ITRF2005 discontinuities is soon to be finalized.
A couple of new coordinate solutions are now generated on regular basis, which provide coordinates in higher resolution and in shorter latency. This is the new *daily* sub-network combination from analysis using IGS final orbits that focuses on higher resolution compared to the weekly combination, and there are now also *rapid daily* combinations from analysis using IGS rapid orbits with a latency of less than one day. The short latency results may serve for monitoring purpose of the EPN network. Tests for combination of even hourly results for the EPN are going on.

1 Introduction

16 so-called Local Analysis Centres (LACs) continuously provide weekly coordinate solutions for GPS tracking stations of the EUREF Permanent Network (EPN), where each of them delivers a dedicated sub-network solution. Normal equations of the sub-network solutions are combined into the EUREF weekly solutions and published through EUREF data centres. All LACs use common options and models to ensure consistency of the sub-network solutions. With the beginning of GPS week 1400 the LACs changed uniformly the following processing options:

- Apply absolute PCVs instead of relative
- Refer to ITRF2005 reference frame instead of ITRF2000
- Update of the ocean loading model to the FES2004 quantity for stations
- Estimation of horizontal troposphere gradient parameters
- Use of low-elevation data (down to 3 degrees) now permitted
- Inclusion of GLONASS observations now permitted

The consistency between the particular LAC contributions improved significantly, as could be seen from Figure 1. Details for the first two listed changes (absolute PCV and ITRF2005) will be shown in the following chapters. Final IGS orbits and Earth rotation parameters are applied in the analysis procedures to generate the *weekly* EUREF solutions and thus cause a typical delay of about 3 weeks for providing the solutions to the public. This considerable latency of the product availability poses to generate some additional products with significant shorter delay. The LACs and the Analysis Coordinator (AC) initiated for that reason the generation of rapid and near real-time solutions, which will be discussed below.

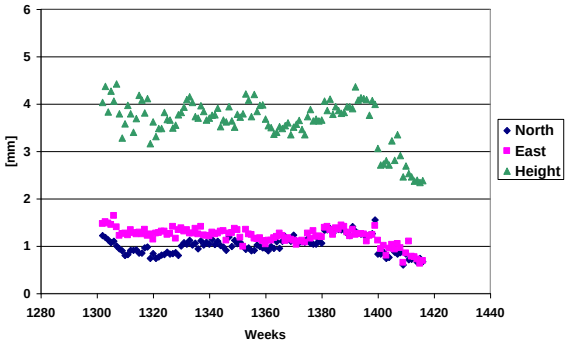

Figure 1: Consistency between EPN Local Analysis Centres

2 Antennae Absolute Phase Centre Variations

The general complex of problems for absolute i.e. relative PCVs has been discussed within the IGS community since a long time [IGS-Mail] and will not be repeated here. The introduction of absolute PCVs into the EPN became difficult by the fact that antennae, which are not listed in the IGS PCV table, occupy a couple of EPN stations. The EPN LACs decided to extend the IGS table with antenna-specific absolute PCVs, if it is available. More details on that topic are available on the [EPN Central Bureau] website. Figure 2 shows height changes, which occurred when the sub-network of BKG LAC was processed with absolute and relative PCVs, respectively, for GPS week 1474. Antenna/dome types order the height changes. For some types we observe common height changes, whereas other types show several changes. Nearly 50 % of the stations experience height changes of larger than 5 mm and up to 30 mm. Note that minimum constrained conditions for the reference stations in the network analysis may affect this result.

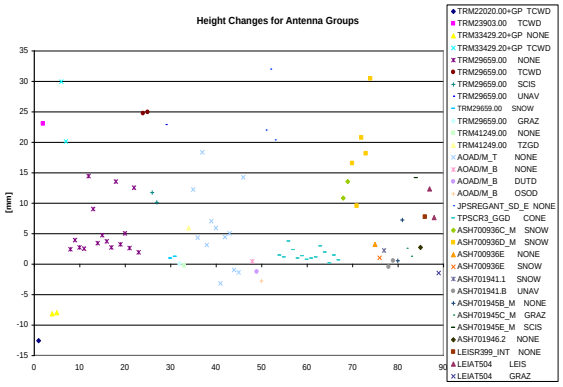

Figure 2: Comparison of Relative and Absolute PCV

3 ITRF2005 Reference Frame

The IGS orbits and Earth rotation parameters refer to ITRF2005 since GPS week 1400 and it became thus mandatory to introduce the ITRF2005 reference frame into the EPN analysis steps at the same time, to reach the best possible consistency between IGS and EPN. This means in practise to apply updated coordinates and velocities to the reference stations during the analysis procedures. It has however to be considered that the ITRF2005 station coordinates of GPS observing sites are based on relative PCVs and could not be directly applied in GNSS analysis where absolute PCVs are actually used, as is the case for EPN since week 1400. But we directly benefit from improved velocity vectors of ITRF2005 due to the consideration of a longer observation interval compared to former ITRF realizations. Velocities result equally for a strict absolute and relative PCV analysis approach respectively. We furthermore

must account for systematic differences between ITRF2005 and the former used ITRF2000, and we need updated transformation parameters to transform the EPN results into the ETRS89 realization. To get rid of the absolute against relative PCV dispute in the current data analysis, the LACs apply actually the IGS05 realization of ITRF2005, which has been determined by IGS after correcting station specific height changes derived from a parallel analysis of using relative and absolute PCVs, respectively, and a subsequent realignment to ITRF2005. The generation of IGS05 has been discussed and published in [IGS-Mail].

The "Memo" [Boucher/Altamimi, 2007] has been updated to transform coordinates from ITRF2005 to an ETRS89 realization. The EPN coordinate results are now given in IGS05 and formally have to be transformed into ITRF2005 before we could apply the transformation formula and parameters from the Memo. Alternatively we could ignore the IGS05 to ITRF2005 conversion, if we confirm that both reference frames are in alignment within the precision of the coordinates. IGS05 has been aligned to ITRF2005 on the global level, but it has to be tested if this alignment persists for a regional network, e. g., the EPN. The *station-specific* height changes as they occur after introducing the absolute PCV could not be considered in a common set of Helmert transformation parameters. The Helmert transformation, as a coordinate operation that is equally applied to all stations, becomes meaningless to reduce the mentioned station-specific height changes. Such could merely reduce the effect "in the mean", but without any geometrical interpretation of that "mean". Table 1 shows a comparison of IGS05 and ITRF2005 coordinates on the global and the regional scale. The estimated translation parameters in X-, Y- and Z-axis direction and the corresponding RMS values are given. The comparison of the global sets of coordinates results in TX=TY=TZ=0 and confirms the alignment of IGS05 and ITRF2005. The significant large RMS for the height component of 7.4 mm could be explained by the station-specific height differences. The comparison for regional sets of coordinates (here EPN sites) has been performed **first** directly without any Helmert transformation (indicated by dashes for TX, TY and TZ in Table 1) and **secondly** with solving for 3 translation parameters. The first approach is equivalent to fix the 3 Helmert parameters to zero and the resulting RMS number are in the same order as found for the global coordinate set comparison. We conclude that the regional sub-set of IGS05 stations, as given by those EPN sites that belong to the IGS tracking network, are aligned to ITRF2005 as good as on the global scale and it requests no additional transformation from IGS05 to ITRF2005 for EPN results. The second approach estimated the 3 translation parameters to small numbers from 0.1 mm in X and -4.7 mm in Y direction. The rms value increases for the North and decreases for the Height component. Considering the rms numbers the estimated translation parameters are not significant.

File 1	File 2	TX [mm]	TY [mm]	TY [mm]	RMS N [mm]	RMS E [mm]	RMS U [mm]
IGS05 (global)	IGT05	0.0	0.0	0.0	1.5	1.3	7.4
IGS05 (EPN sites)	IGT05	-	-	-	1.0	1.3	7.9
		-3.3	0.1	-4.7	1.9	1.4	5.2

IGT05 = IGS sites of ITRF2005

Table 1: Helmert transformation between IGS05 and ITRF2005 coordinates

A comparison of IGS05 coordinate numbers versus ITRF2005 for the EPN sites of the IGS05 stations is given in Figure 3. The property "station-specific" is clearly visible for the height differences. It is also obvious that the correction for a *mean* height change, as would be applied by a translation step between IGS05 and ITRF2005, is not meaningful.

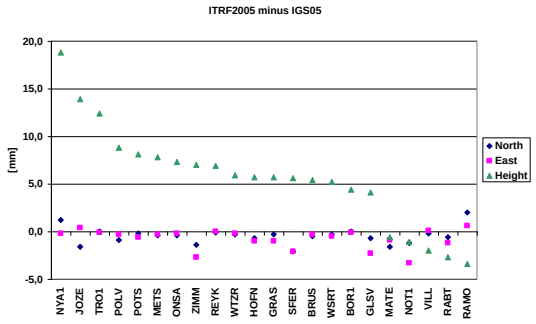

Figure 3: Comparison IGS05 vs. ITRF2005 for EPN Sites of IGS05

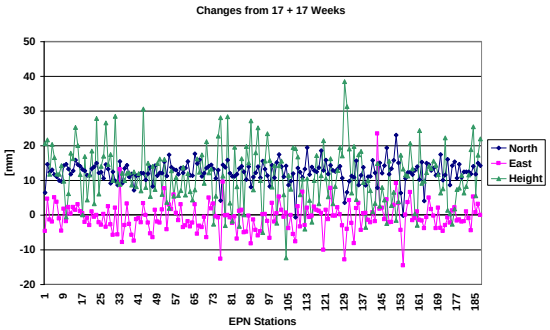

Figure 4: Week 1400 Differences

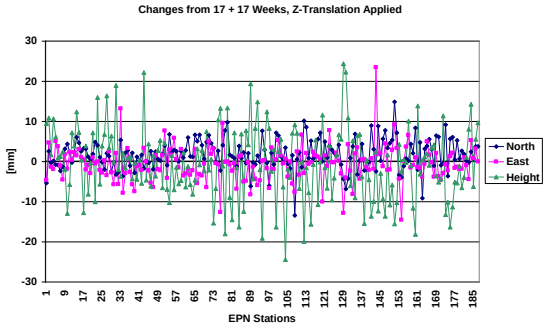

Figure 5: Week 1400 Difference, Z-Shift of 16.2 mm applied

4 EPN Time Series in ITRF2000 and ITRF2005

There were recently 17 weekly EPN solutions after the significant changes of analysis options since week 1400 available. The corresponding normal equations were stacked into combined solutions and compared to a combined solution from 17 weeks before the changes. The coordinate differences are given in Figure 4. We observe a systematic change in the North and Height component. Furthermore the Height component is superposed by station-specific changes. The systematic part of the differences is caused by a shift along the Z-Axis between ITRF2000 and ITRF2005. For the European region a Z-shift is equivalent to a certain shift in North and Height, where the East component is not affected. If we apply a Z-shift of 16.2 mm to all coordinates before the comparison, the systematic differences escape, but the station-specific height differences remain (see Figure 5).

It has to be mentioned here, that the new release of transformation parameters to convert from ITRF2005 to an ETRS89 realization is under investigation. New aspects for that transformation has to be considered due to the drift between the ITRF2005 and former ITRF realizations, e.g., ITRF2000. We give no coordinate comparisons in ETRF here at this time.

5 EPN Rapid Solution

At the EUREF Technical Working Group (TWG) meeting in November 2006 it was proposed to initiate an EPN Rapid Analysis as a *daily* processing and combination of the EPN sub-networks. It was stated that there exists a clear need for information of performance and condition of the full EPN without long latency. The idea is to run a daily analysis within 24 hours after end of observation. During the preparation phase for that new product the following 3 alternative options for the combination showed up:

- **Option 1**, daily SINEX files from IGS final orbits
- **Option 2**, daily SINEX files from IGS rapid orbits
- **Option 3**, daily SINEX files from both, IGS final and rapid orbits

The clear majority of LACs that responded to a questionnaire voted for option 3, which means to generate 2 daily EPN

combined products: One from IGS final orbits and a second from IGS rapid orbits. 7 LACs are currently submitting SINEX files from IGS final and 5 even from IGS rapid orbits. The daily combined SINEX files of the last recent 7 days are additionally combined and such combinations result in *rapid weekly* products. The available solutions may be specified as:

Daily combination from rapid IGS orbits,

- product generation at 22:00 UTC every day
- product delay of < 1 day
- product files:

`EURwwwwdR.CRD/SNX/SUM` , d=[0-6]
`EURwwwwMR.CRD/SNX/SUM`
, combination of the 7 most recent days

Daily combination from final IGS orbits,

- product generation at 04:20 UTC every day
- product delay of currently 30 days
- product files:

`EURwwwwd.CRD/SNX/SUM`, d=[0-6]
`EURwwwwM.CRD/SNX/SUM`
, combination of the 7 most recent days

More details about the development of the daily products are available in EPN LAC-Mail no. 0755, 0758, 0759 and 0778 [EPN Central Bureau].

6 Near Real-Time Solutions

Additionally to the daily and rapid daily solutions 3 LACs confirmed to provide hourly SINEX files to generate an hourly EPN combined product for purpose of near real-time monitoring of EPN stations. We consider this action as a "demonstration phase" and after first experience we may decide on long-term hourly analysis/combination. For hourly product files we assign the following file names:

`acnwwwwd_hh.snx`
`EURwwwwd_hh.snx/sum/crd`,

where d = [0-6] day of the week and hh = 00 - 23 hour of the day.

The following sub-directories at the BKG data centre hold the hourly files:

`EUREF/products/wwww/nrtd`,

where d = [0-6] day of the week "nrt" is a fixed name and indicates the near real-time meaning of the sub-directories.

The hourly combination runs each hour at minute 55. It results in a latency of < 1 hour. The full EPN coordinate combination product schema is shown in Figure 6.

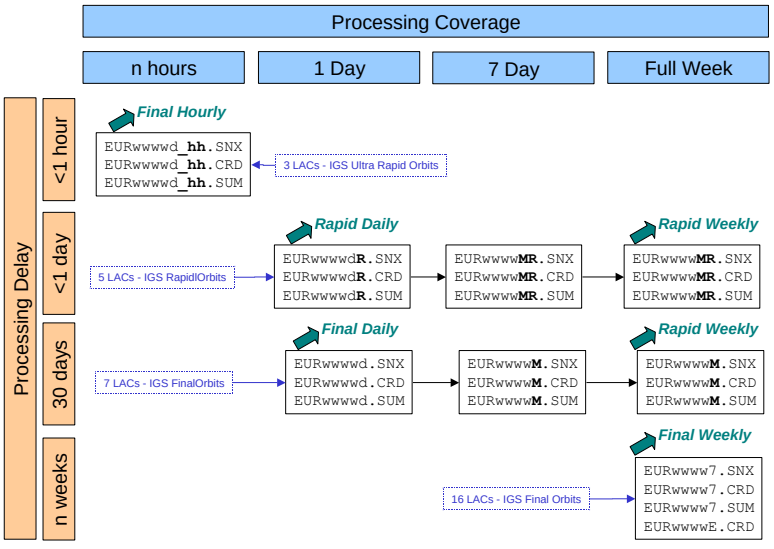

Figure 6: EPN Coordinate Combination Product Series

7 Outlook

There are many users within Europe, which refer their daily applications to ETRS89 and they intend to use the EPN for ETRS89 realization. This requires however to transform EPN coordinates from ITRF2005, as given by the analysis results from the LACs/AC, into the ETRF. The corresponding transformation parameters are now under discussion within the EUREF TWG, because new aspects need to be considered within the ITRF to ETRF relation, since the ITRF2005 global realization differs significantly from former ITRF realizations. User requirements will be taken into account as best as possible during the evaluation of an updated conversion schema. A regional densification of the ITRF2005 is going to be provided by a multiyear combination of all EPN weekly solutions. For the time being it is recommended to use the results of the EPN Coordinate Time Series Special Project [EPN Central Bureau] instead.

8 References

IGS-Mail: Website of the International GNSS Service at http://igscb.jpl.nasa.gov

C. Boucher, Z. Altamimi [2007]: *Memo : Specifications for reference frame fixing in the analysis of a EUREF GPS campaign*, http://lareg.ensg.ign.fr/EUREF/memo2007.pdf

EPN Central Bureau: Website at http://www.epncb.oma.be