EPN Special Project "Troposphere Parameter Estimation" – Status Report

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Abstract

Since June 2001, the Local Analysis Centres (LACs) of the EUREF Permanent Network (EPN) have been delivering daily troposphere solution files, which are created during the computation of the weekly coordinate solution with little additional effort. The combination of these solutions is carried out as a part of the EUREF Special Project "Troposphere Parameter Estimation".

After one year of processing a first summary report is given. The progress in estimation and in participation in the project is shown. The rules for the combination are briefly explained. Improvements resulting from the new EUREF processing options used since GPS week 1130 are outlined. Remaining discrepancies within the results are discussed. Comparisons between the two combination solutions provided by BKG and GFZ are shown.

Introduction

The troposphere is known as one limiting factor for the estimation of the ellipsoidal height component because water vapour is one of the major error sources during geodetic positioning with GPS. On the other hand, it is possible to estimate zenith atmospheric path delays and to derive the content of integrated water vapour in the atmosphere from GPS observations. If no or not only an a priori troposphere model is used troposphere parameters are part of the set of unknown parameters during the routine analysis of ground-based GPS networks with scientific software packages. The results can be useful for meteorological purposes to improve weather forecasting [V. D. MAREL, WEBER 2002]. With longer series of estimated Zenith Total Delay (ZTD) values e.g. climate monitoring and climate research can be supported in the future if the accuracy and the long-term stability are high enough.

The EUREF Permanent Network (EPN) is a well distributed and dense network of more than 120 sites. For many years, this network has been routinely processed by a number of so-called Local Analysis Centers (LACs) for the purpose of coordinate adjustment and time series analysis. With this experience in mind, EUREF decided to establish a Special Project "Troposphere Parameter Estimation". Starting with GPS week 1108 the first LACs have begun to deliver daily troposphere solution files, as a result a few weeks later the first combination solution could be computed. The daily troposphere files have been produced at the end of the routine weekly analysis. The chronological course of the Special Project is given in table 1. Since GPS week 1143 all 15 LACs are sending the troposphere solutions.

Tab. 1: Chronology of the Special Project

GPS week	Event
1108	Contribution of BKG
1109	Contribution of UPA
1110	Contribution of ASI and COE
1110	First combination at BKG
1111	Contribution of IGN and LPT
1112	Contribution of OLG
1113	Contribution of WUT
1114	Contribution of NKG
1115	Contribution of GOP
1116	First combination at GFZ
1120	Contribution of BEK
1126	Contribution of IGE
1130	New EUREF processing options: 10 degree elevation cutoff angle / Elevation-dependent weighting / Use of the "Dry Niell"-mapping function / 1 hour troposphere solution / Use of the IGS final orbits Additional new options: Fixing (constraining) solutions to ITRF 97 coordinates / Re-substitution of weekly SNX solution
1130	Contribution of DEO and ROB
1143	Switch to new reference frame ITRF 2000
1143	Contribution of SGO

Beginning with GPS week 1130 new EUREF processing options should be used by the LACs for their weekly analysis. One reason for the introduction of the new options was the attempt to standardize the analysis of the LACs, another one was the request for improving the coordinate solution. Two additional options concerning the coordinates used during the final run of the troposphere parameter estimation were introduced by the EUREF analysis coordinator. One reason was to maintain consistency between the weekly coordinate solution and the daily troposphere solutions of one individual LAC. The other reason was to get a better consistency between the troposphere solutions of different LACs since there is a high correlation between the troposphere parameters and the height component. Table 2 shows the actual status of the parameter settings at the different LACs. The substitution of the weekly coordinate solution during the

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final estimation of the daily troposphere solutions was proven just by comparing the coordinates manually. Up to now not all centres have been able to realize all of the demanded options.

Combining the individual daily troposphere solutions yields to the final EUREF product, the weekly combined troposphere solution. A combination is appropriate since the observations of each site are analysed by at least three different LACs. The combination is carried out using the procedure described in [GENDT 1997] for the IGS troposphere combination. Input data with high standard deviations are rejected from the start with a criterion value of e.g. 30 mm. After a preliminary bias calculation there is an epoch-wise outlier detection taking these biases into account. After that, there may be an additional rejection of complete data series for each LAC, site and day, if the standard deviation is too high, e.g. more than 20 mm. Finally there is the computation of epoch-wise weighted mean values taking into account the final LAC-dependent biases. With this step jumps in the mean series are avoided if single observations are not available.

Tab. 2: Options and parameter actually (June 2002) used by the LACs

LAC	Sampling [hours]	Cutoff elevation [deg]	Troposphere Model	Software	Fixing coordinates	Re-Substitution of SNX	No. of sites analyzed
ASI	2	15	1/cos(z)	MicroCosm	yes	(yes?)	~ 22
BEK	1	10	Dry Niell	Bernese	yes	yes	~ 34
BKG	1	10	Dry Niell	Bernese	yes	yes	~ 45
COE	1	10	Wet Niell	Bernese	yes	yes	~ 37
DEO	1	10	Dry Niell	Gipsy	no	(yes?)	~ 23
GOP	1	10	Dry Niell	Bernese	yes	yes	~ 31
IGE	1	10	Dry Niell	Bernese	yes	yes	~ 16
IGN	1	10	Saastamoinen	Bernese	no	no	~ 23
LPT	1	10	Dry Niell	Bernese	yes	yes	~ 18
NKG	1	10	Dry Niell	Bernese	yes	yes	~ 32
OLG	1	10	Dry Niell	Bernese	yes	yes	~ 35
ROB	1	10	Dry Niell	Bernese	yes	yes	~ 26
SGO	1	10	Dry Niell	Bernese	yes	(yes?)	~ 15
UPA	1	15	Saastamoinen	Bernese	yes	yes	~ 21
WUT	2	10	Dry Niell	Bernese	yes	(yes?)	~ 30

Results

In this chapter the main results of the troposphere parameter combination are shown. The figures 1 and 2 show the weekly mean biases and the standard deviations as taken from the weekly summary files of the BKG combination for all Local Analysis Centres. In the first weeks the number of contributing LACs was still changing (compare table 1), since GPS week 1143 the number is constant. Following GPS week 1130 when the new processing options have been applied an improvement in the biases as well as in the standard deviations can be seen. The weekly mean biases of most of the centres have been reduced to ± 2-3 mm ZTD except for the two LACs DEO and IGN which do not fix the weekly coordinate solution to ITRF (table 2). This affects very much the daily troposphere solutions. The standard deviations are mainly below 3-4 mm ZTD for the actual weeks.

Within the figures 3 and 4 the distribution of the site-dependent weekly mean biases and standard deviations for every local analysis centre is given. The main peaks in figure 3 should be close to zero (i.e. no biases) which is fulfilled for most of the LACs. For the LACs DEO and IGN the highest number of biases is shifted to –5 with the same reason of not fixing the coordinate solution to ITRF as described above. The site-specific standard deviations are below 5 mm with the exception of centre ASI. Explanations are that ASI is still solving for the troposphere parameters in two hour intervals and that ASI is using another software. Therefore the ASI solution may be a little ”underestimated” within the combination with the other LACs using the same software.

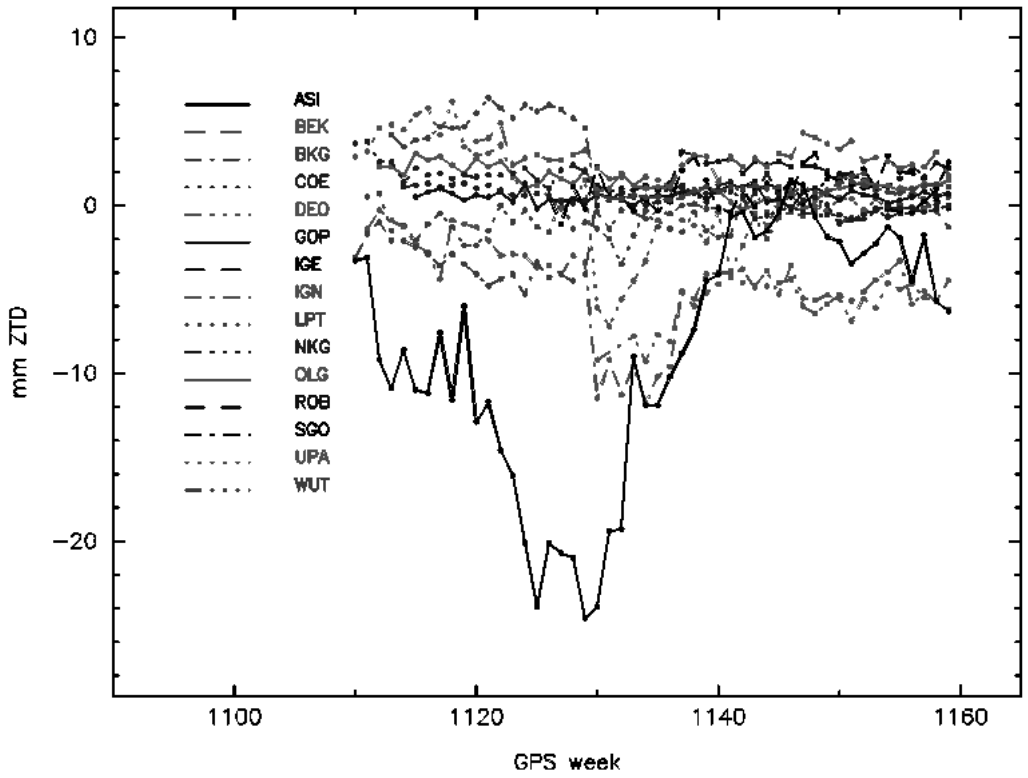

Fig. 1: Weekly mean biases for the Local Analysis Centres

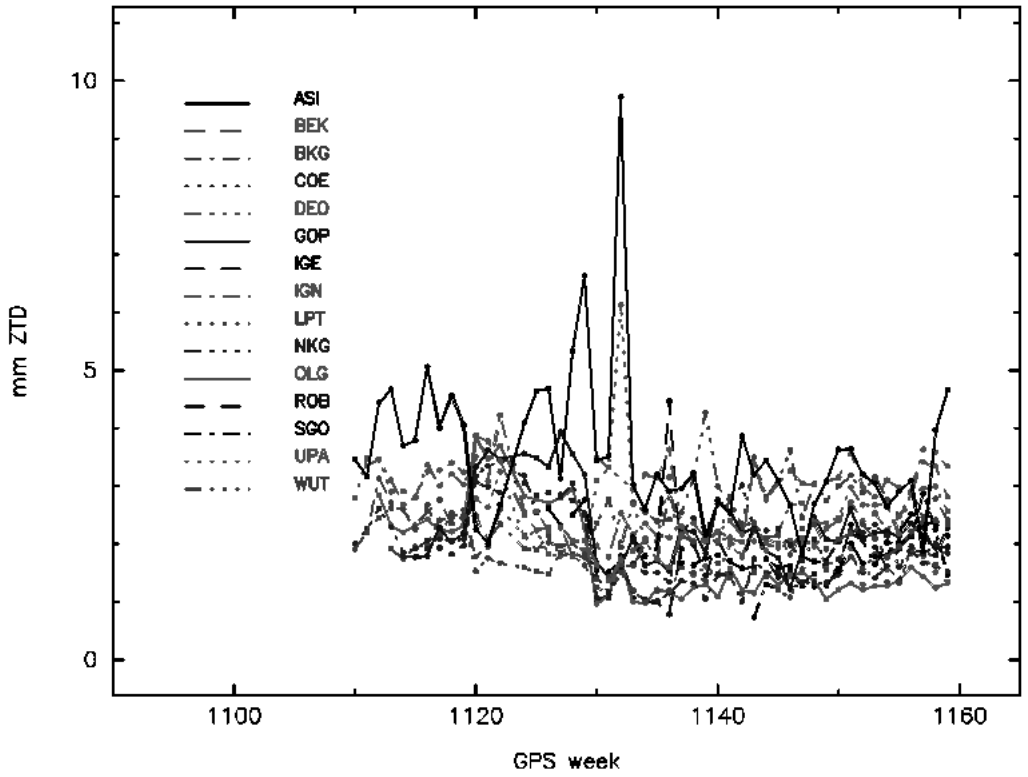

Fig. 2: Standard deviation of the weekly mean biases

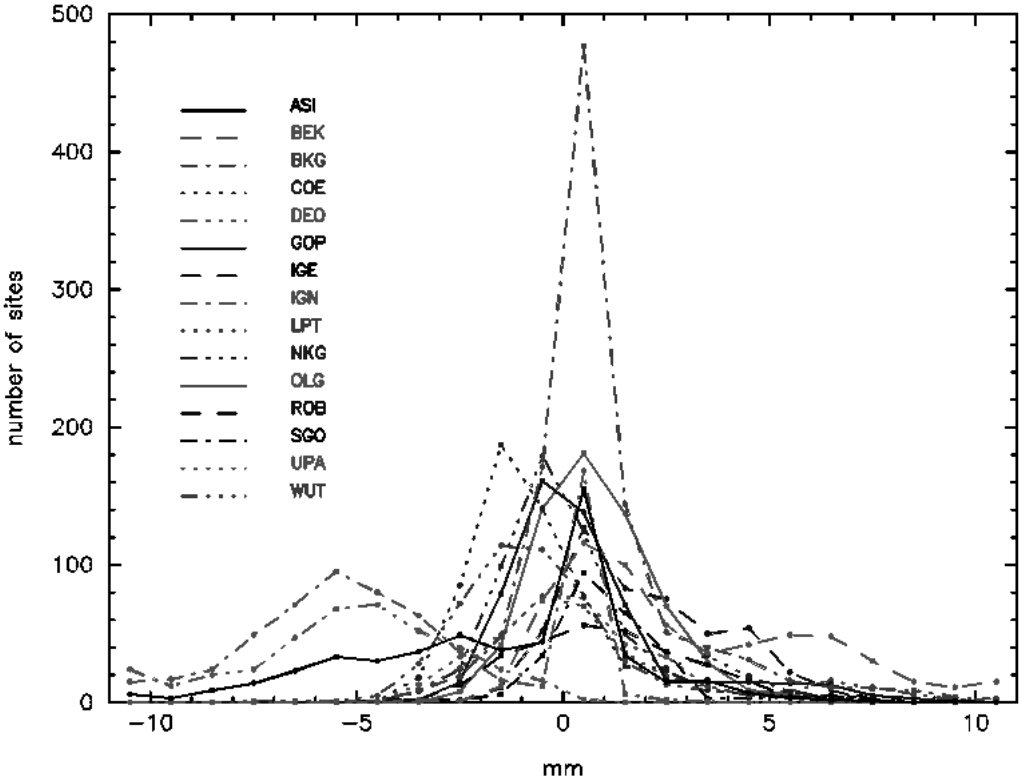

Fig. 3: Histogram of site-specific weekly biases for the Local Analysis Centres (GPS weeks 1143-1159)

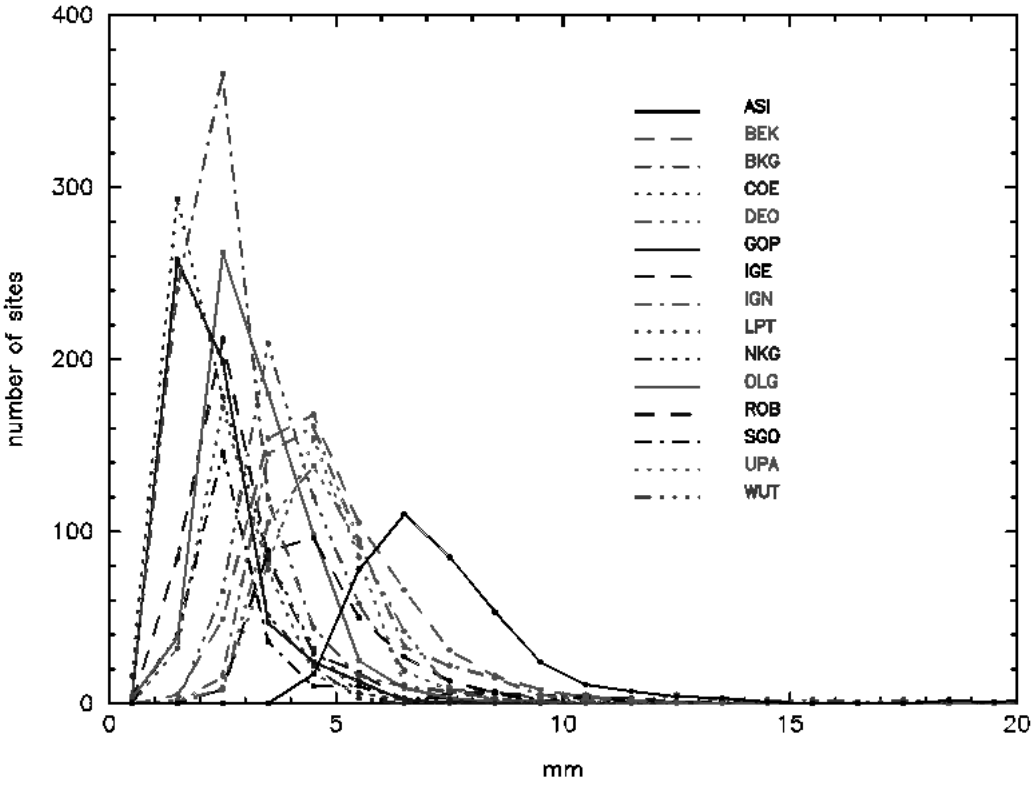

Fig. 4: Histogram of site-specific standard deviations (GPS weeks 1143-1159)

Figure 5 shows the mean bias between the two combination solutions of BKG and GFZ. Although in principle both combination centres are using the same combination procedure there are some small differences in the realization. This refers to the outlier detection and the bias calculation. At the beginning (before GPS week 1130) there were some bigger discrepancies probably due to different weighting of some individual LAC solutions. Especially for the GPS weeks 1130-1133, right after the changes of the processing options, the mean bias reached 2-3 mm ZTD which could not be explained yet, even not with some re-computations. For the actual weeks the weekly mean bias has been stabilized in the range of ± 0.2 mm ZTD with a standard deviation of about 0.6 mm.

In figure 6 the weekly mean biases between the two EPN combined solutions of BKG and GFZ and the IGS troposphere combined solution is shown. The IGS weekly solution is a combination of the weekly solutions of seven Analysis Centres which all are analysing data of globally distributed stations and most of them are using different software packages [Gendt 1997], [Gendt 1998]. There are about 45 IGS sites which are also analysed in the EPN solutions. The weekly mean biases are in the range of 2-3 mm ZTD with nearly the same standard deviation. These values are in the same order of magnitude as the biases and standard deviations of an individual analysis centre solution within the IGS troposphere combination [GENDT 1998].

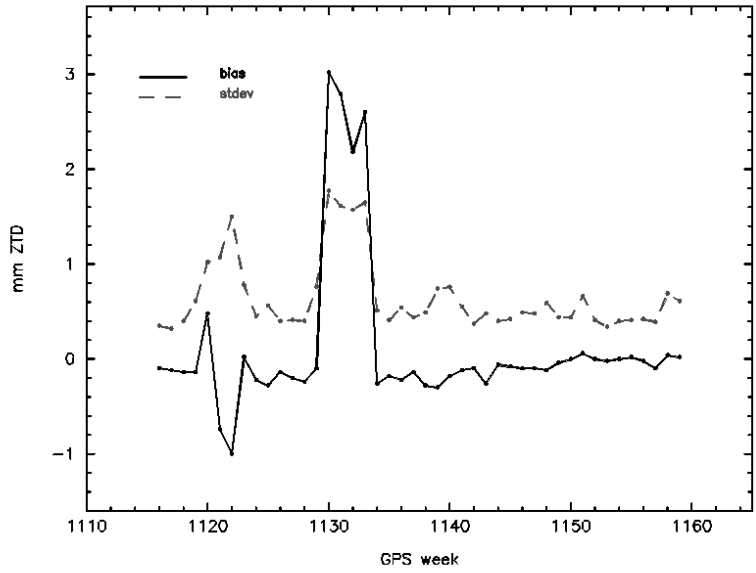

Fig. 5: Bias and standard deviation between BKG and GFZ weekly combined solutions

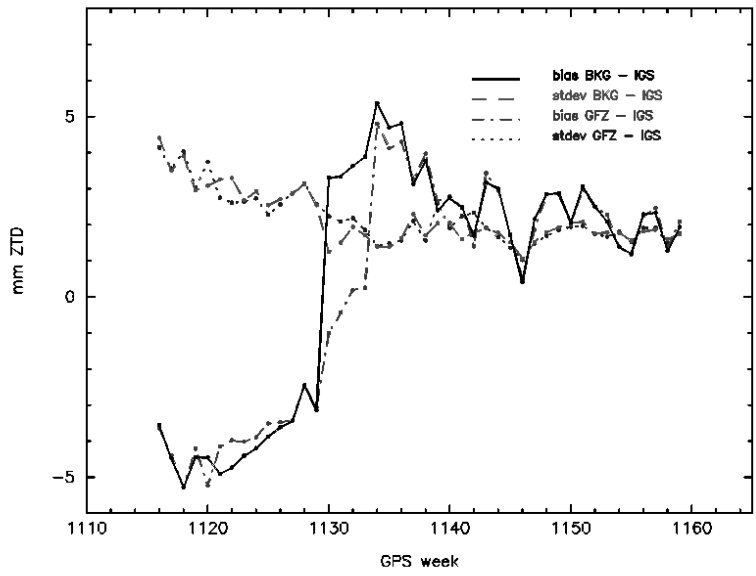

Fig. 6: Bias and standard deviation compared to IGS solution

Conclusions

The weekly mean biases of the Local Analysis Centres are mainly below 3 mm, the standard deviations of the weekly mean biases are below 3-4 mm. Within a re-computation test of about 20 weeks it will be investigated if a further reduction of the mean biases can be reached by introducing and constraining the coordinates of the EUREF combined solution.

The following products are available at the BKG Data Analysis Centre ('wwww' is the GPS week):

- ftp igs.ifag.de (via anonymous ftp)
- cd EUREF/products/wwww
- LACwwwwd.TRO individual solution for day 'd' of analysis center 'LAC'
- EURwwww7.TRO combined solution by BKG
- EURwwww7.TSU summary for combined solution of BKG
- GFZwwww7.TRO combined solution by BKG
- GFZwwww7.TSU summary for combined solution of BKG

For the near future it should be stated that all Local Analysis Centres use the common and correct set of options and parameters.

A standardization between the procedures and formats used at the two combination centres is desirable for closer results and better use of the combination products.

One point of interest is the question if the EUREF combined solution can be taken as input in the global IGS troposphere combination. For this point the latency of the individual LACs daily troposphere solutions must be restricted to a certain date, e.g. four weeks after the last observation. On average, 11-13 LACs meet this requirement.

A last question is if we can get longer time series of zenith total delay values with re-calculation of past data. If daily normal equations - including troposphere parameters - were available, this could be done with relatively few additional amount of work.

Acknowledgement

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- Bavarian Academy of Sciences and Humanities, Germany (BEK)
- Federal Agency for Cartography and Geodesy, Frankfurt, Germany (BKG)
- FOMI Satellite Geodetic Observatory, Budapest, Hungary (SGO)
- University of Padova, Italy (UPA)
- Italian Space Agency (ASI)
- Delft University of Technology, The Netherlands (DEO)
- Warsaw University of Technology, Poland (WUT)
- Instituto Geografico Nacional, Spain (IGE)
- Nordic Geodetic Commission, Sweden (NKG)
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- Astronomical Institute of the University of Berne, Switzerland (COE)

the EPN Special Project "Troposphere Parameter Estimation" could not start a combination process and cannot maintain the investigations. This collaboration is gratefully acknowledged.

References

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