Status Report of the EPN Special Project "Troposphere Parameter Estimation"

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Abstract

This contribution summarizes the activities of the Special Project "Troposphere Parameter Estimation" with focus on the combination of the individual solutions of Zenith Total Delay parameters computed by the Local Analysis Centres. The report draws attention to the change from Bernese software version 4.2 to version 5.0 – which concerns to 14 of 16 Local Analysis Centres – including changes of input and output parameters and processing options.

Overview

Since GPS week 1108 (June 2001) the Local Analysis Centres (LACs) of the EUREF Permanent Network (EPN) have been delivering weekly solutions of Zenith Total Delay (ZTD) parameters. The solutions are in the so-called troposphere SINEX format. Since GPS week 1185 all 16 LACs are participating. Figures 1 and 2 show the ZTD time series for two stations KARL and PFAN which are approximately 200 km apart with a height difference of approximately 900 m. Nevertheless the good overall agreement can be seen by a correlation coefficient of 0.82. The main ZTD difference of –265 mm together with the height difference of +907 m results in a transformation factor of -0.29 mm ZTD per m height difference which, despite the distance between the two sites, is in good agreement with the rule of thumb usually used for height difference correction [SCHUH et al., 2004].

From the beginning of the special project the combination has been carried out by two different centres, "GeoForschungsZentrum Potsdam" (GFZ) and "Bundesamt für Kartographie und Geodäsie" (BKG). With GPS week 1307 GFZ stopped the combination as a results of some major changes in the structure of the IGS.

14 out of the 16 LACs are using the Bernese GNSS software, version 4.2. Minor changes in the software reported in the so-called "Bernese user mail" could be easily applied by the different user groups without important influence on the results. Since the beginning of 2005 a new version 5.0 of the software is available (see [SCHAER, 2005] for more details). The new version should facilitate the use by a predefined analysis scheme (RNX2SNX) which is aligned to the application of the analysis of daily files. The software has some new options which are used as default values or entrees in this scheme. The impacts of changes of some options or parameters to the ZTD estimation are discussed in the next chapter. A small network of 17 European stations is analysed in a 24 hours static solution for these tests.

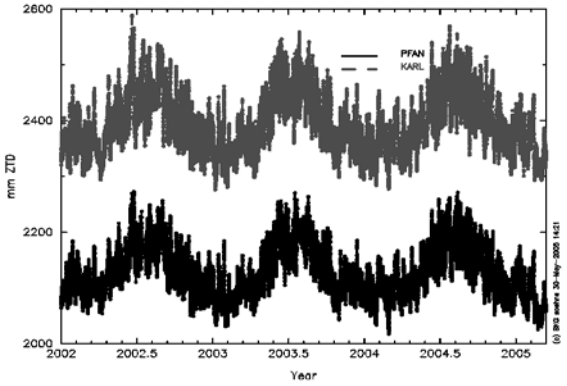

Fig. 1: Time series of Zenith Total Delay (ZTD) values for sites KARL and PFAN from EPN combined solution

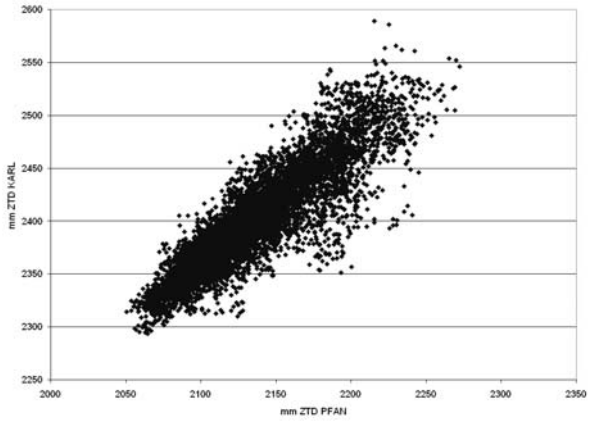

Fig. 2: Histogram for ZTD values of sites KARL and PFAN, correlation 0.82

Impact of parameter changes on ZTD parameters

Niell mapping function

In GPS week 1130 a number of EUREF processing options was introduced for use at the LACs [SÖHNE, WEBER, 2003]. One of them was to estimate the complete atmospheric delay with the Dry Niell mapping function. No a priori troposphere correction was applied. Background for this decision was that the Bernese software version 4.2 was not able to use an a priori hydrostatic delay. In the new Bernese software version 5.0 it is recommended in accordance with [ELGERED et al., 2004] to calculate an a priori

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zenith hydrostatic delay (ZHD_0) which is mapped with the Dry Niell mapping function. In the estimation part the zenith wet delay (ZWD') is calculated using the Wet Niell mapping function. Figure 3 shows the biases between the two approaches. There is a systematic difference of -1 – -2.5 mm ZTD if the approach was changed. These numbers may vary depending on the ZWD. The impact of the change in the troposphere correction on the ellipsoidal heights is in the range of ± 2 mm. If in both variants the coordinates were fixed to the same set of coordinates the pure effect of the change of the troposphere correction can be seen: the – still systematic – biases reduce significantly below 1.5 mm ZTD.

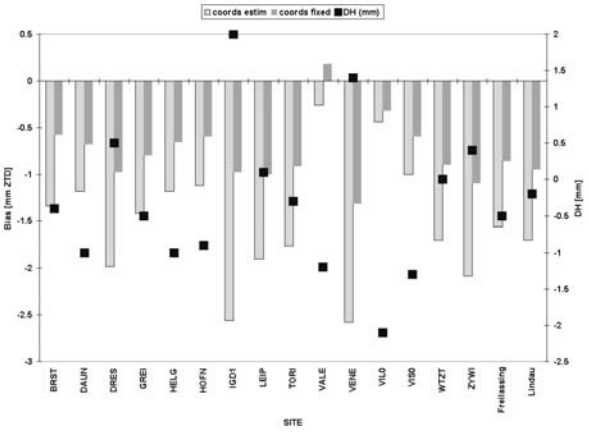

Fig. 3: Differences of ZTD and ellipsoidal height parameters: solution with (a priori/estimated) DRY NIELL/WET NIELL minus NONE/DRY NIELL; left columns and squares from analyses with simultaneous coordinate estimation (WTZT fixed), right columns from analyses with coordinates fixed to same set of coordinates

Horizontal delay parameters

The estimation of horizontal gradient parameters has been integrated in the IGS analyses for some Years [ROTHACHER et al., 1997]. The background was to model azimuthal asymmetries, the improvement should result in a reduction of the repeatability of the estimated coordinates.

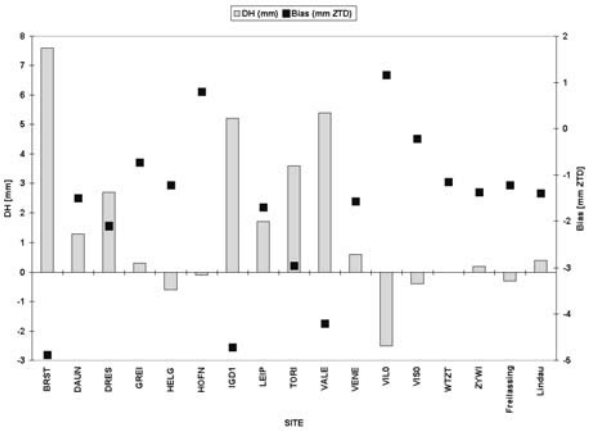

Fig. 4: Differences of ZTD and ellipsoidal height parameters: solution with estimation of horizontal gradient parameters (TILTING) minus solution without horizontal gradient parameters (WTZT fixed)

For Bernese software version 5.0 there is the possibility to estimate horizontal delay parameters in North-South and East-West direction, usually one parameter per day (and direction) for each station. It is not recommended to estimate horizontal gradients in local networks. For the example with 17 European stations a clear impact can be seen (Figure 4). The changes seem to have a dependency on the location: only the northern stations have a positive sign and the biggest differences appear at the southern and western stations. The differences in the ellipsoidal height are up to 8 mm, again the biggest for the stations at the boundary of the network. There seems to be an inclination of the whole network in North-South-direction.

Fixing coordinates

One of the EUREF processing options introduced for the estimation of the ZTD parameters was to fix the coordinates to the weekly solution before finally estimating the daily ZTD parameters, the so-called re-substitution [SÖHNE, WEBER, 2003]. This should reduce the influence of day-to-day height variations on the ZTD estimates and should give consistency of the weekly coordinate solution with the ZTD solutions of each LAC. In Figure 5 two solutions of ZTD parameters are compared, one with simultaneous estimation of both ZTD parameters and coordinates and the other one with ZTD parameter estimation and fixed coordinates. The resulting differences only show a dependency of e.g. positive height difference and corresponding negative ZTD difference for four out of the 17 stations. An absolute size of the impact of coordinate fixing of more than 3 mm ZTD is visible at six stations.

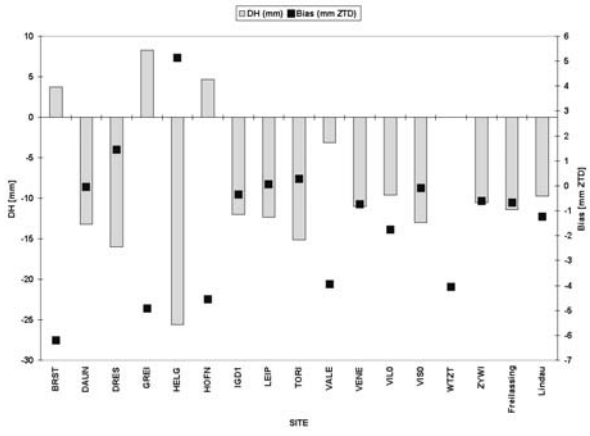

Fig. 5: Differences of ZTD and ellipsoidal height parameters: solution with coordinates fixed (to a priori coordinates) minus solution with simultaneous coordinate estimation (WTZT fixed)

Ocean tide loading corrections

Ocean tide loading (OTL) corrections are applied for every station in the analysed EPN network. If a new station is introduced in the network a new set of correction parameters has to be computed, e.g. with the tool by [BOS, SCHERNECK, 2001]. If the newest correction model was used (which usually is marked as the default model) it may happen that the OTL correction table includes corrections from different models. Figure 6 shows an example for the small test

network of 17 European stations where for one station – HOFN – a correction from another model (CRS4) was used instead of GOT00.2 for all other sites. There is an impact on the ZTD and the ellipsoidal height parameters of the other stations in the network, although the differences are small (< 0.2 mm in height, < 0.15 mm in ZTD). The height difference of 1.7 mm for the station HOFN itself is not negligible leading to the conclusion that especially for sites with higher latitudes a consistent set of OTL parameters is desirable.

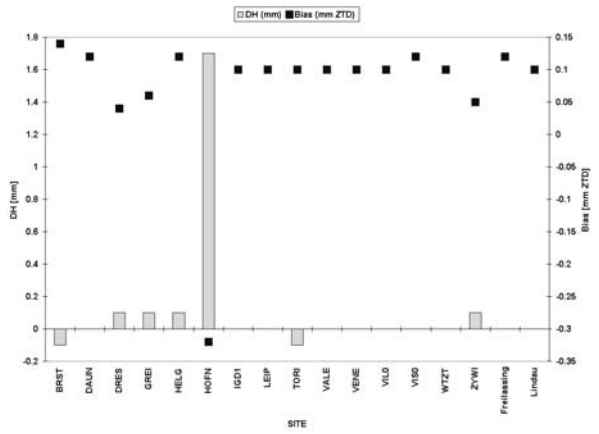

Fig. 6: Differences of ZTD and ellipsoidal height parameters: solution with consistent Ocean Tide Loading (OTL) parameter set minus OTL parameters changed for station HOFN (WTZT fixed)

Impact of change from Bernese software version 4.2 to version 5.0

The impact of the change from version 4.2 – using the EUREF processing options – to version 5.0 – using the script RNX2SNX – is shown in the Figures 7 and 8..

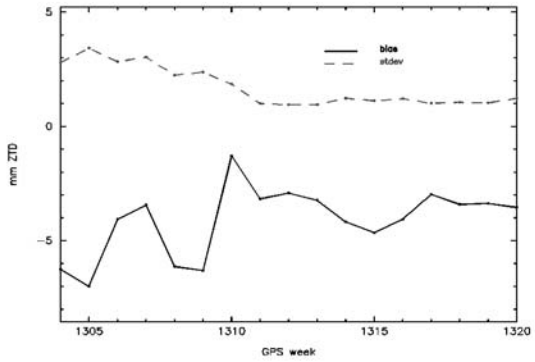

Fig. 7: Weekly mean bias and standard deviation of BKG ZTD estimated values Bernese software version 4.2 vs. version 5.0

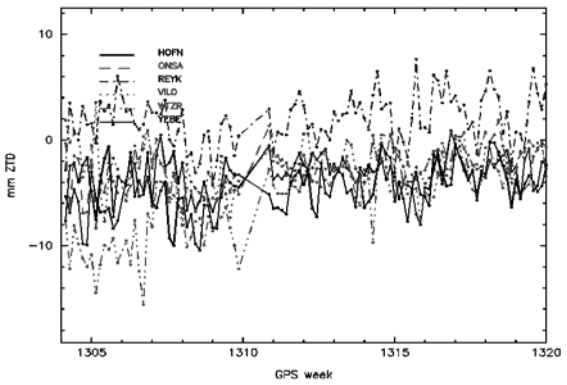

Fig. 8: Weekly mean bias and standard deviation of BKG ZTD estimated values Bernese software version 4.2 vs. version 5.0 for individual sites

Here the two solutions are computed in parallel at the LAC BKG. Before GPS week 1310 the estimation of horizontal gradient parameters was switched on. From GPS week 1311 on the weekly mean bias is nearly constant in the range of –3 to –4 mm with a standard deviation of ± 1 mm. The examples for individual sites confirm the systematic behaviour except for station REYK where the bias is positive

LAC-specific results

In this chapter some site-specific results from the EPN combination will be shown. Figures 9 and 10 show the weekly mean biases for the two sites HOFN and REYK. While the weekly biases for HOFN are relatively stable for the four LACs involved (mean -1.9 to +1.2 mm with ± 0.8 – 1.2 mm rms) for site REYK there is a seasonal signature clearly visible which degrades the rms of the mean of the weekly biases to ± 1.9 – 3.8 mm. One supposition was, this could be the influence of "wrong" (or better: not consistent) OTL corrections. This can be rejected due to the results of the chapter above. The solution for the seasonal signal which mainly occurs on the BKG solution is the procedure of fixing coordinates. From GPS week 1210 on BKG has been fixing the coordinates of REYK. Therefore the seasonal height variations are only visible on the other LACs solutions (Figures 11 and 12). The Figures 11 and 12 also show a small increase of the ellipsoidal height for site HOFN whereas there is a height decrease of site REYK which may be a result of the location on different tectonic plates.

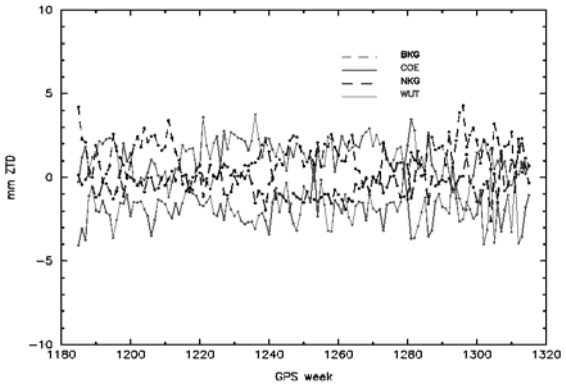

Fig. 9: Weekly mean biases for site HOFN from EPN combined solution for the four involved Local Analysis Centres

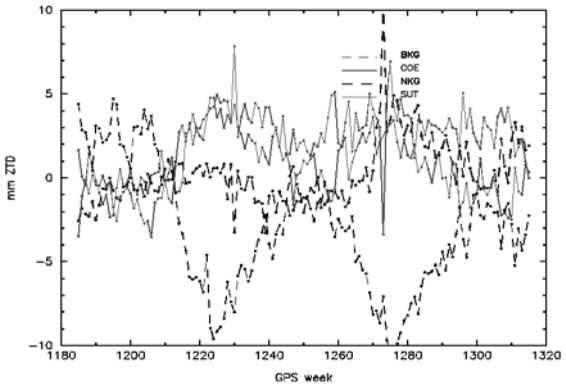

Fig. 10: Weekly mean biases for site REYK from EPN combined solution for the four involved Local Analysis Centres

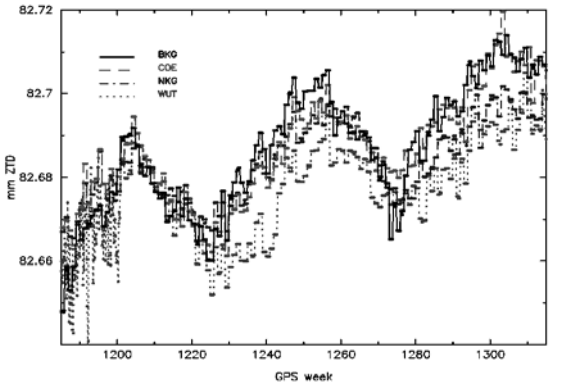

Fig. 11: Estimated ellipsoidal heights for site HOFN taken from combined weekly SNX files

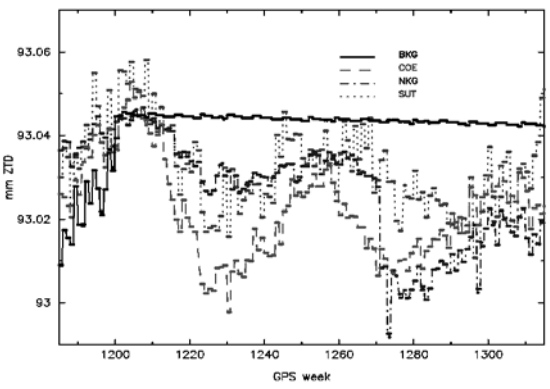

Fig. 12: Estimated ellipsoidal height for site REYK taken from combined weekly SNX files

Acknowledgement

The colleagues of the 16 Local Analysis Centres ASI, BEK, BKG, COE, DEO, GOP, IGE, IGN, LPT, NKG, OLG, ROB, SGO, SUT, UPA and WUT is gratefully acknowledged for their effort in permanently analysing the data of the EUREF Permanent Network.

References

[BOS, SCHERNECK, 2001]: BOS, M.S., H.-G. SCHERNECK – *Automatic ocean loading provider*, IGSMAIL-3521, (www.oso.chalmers.se/~loading)

[ELGERED et al., 2004]: ELGERED, G., H.-P. PLAG, H. VAN DER MAREL, S. BARLAG, J. NASH (Eds.) – *COST716 Exploitation of Ground-based GPS for Operational Numerical Weather Prediction and Climate Applications – Final Report*, (www.oso.chalmers.se/~kge/cost716.html)

[ROTHACHER et al., 1997]: ROTHACHER, M., T.A. SPRINGER, S. SCHAER, G. BEUTLER – *Processing Strategies for Regional GPS networks*, IAG Symposia, vol. 118, pp. 93-100

[SCHAER, 2005]: SCHAER, S. – *EUREF LAC analysis at swisstopo/CODE using Bernese software V5.0*, Report on the Symposium of the IAG Subcommission for Europe (EUREF), Vienna, 01-04 June 2005, (this volume)

[SCHUH et al., 2004]: SCHUH, H., K. SNAJDROVA, J. BOEHM, P. WILLIS, G. ENGELHARDT, R. LANOTTE, P. TOMASI, M. NEGUSINI, D. MACMILLAN, I. VERESHCHAGINA, V. GUBANOV, R. HAAS – *IVS Tropospheric Parameters – Comparison with DORIS and GPS for CONT02, IVS 2004 General Meeting Proceedings*, p. 461-465

[SÖHNE, WEBER, 2003]: SÖHNE, W., G. WEBER – *EPN Special Project "Troposphere Parameter Estimation" – Status Report*, Report on the Symposium of the IAG Subcommission for Europe (EUREF), Ponta Delgada, 05-08 June 2002, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 29 (EUREF publication No. 12)