

# TropMon – a new Analysis Tool for BKG’s Troposphere Parameter Databases

W. Söhne, A. Stürze

Federal Agency for Cartography and Geodesy, Richard-Strauss-Allee 11, 60598 Frankfurt am Main, Germany

M. Vennebusch, S. Schön

Institut für Erdmessung, Leibniz-Universität Hannover, Hannover, Germany

**Abstract.** Zenith Path Delay (ZPD) parameters are estimated during GNSS network processing within the EUREF Permanent Network (EPN) for several years now. Usually, the interface for these parameters is the so-called SINEX TRO format. Within the EPN, the TRO files are combined since 2001 when the Special Project “Troposphere Parameter Estimation” started. Since 2007, the combination switched over to routine operation. Using various shell and perl scripts as well as Fortran programs the combination produces several outputs like combined TRO files and summary files of the combination process which could be downloaded via ftp from the BKG data centre as well as site-specific ZPD and bias plots which are displayed on the web page of the EPN Central Bureau (EPN CB).

One interesting issue is the comparison or combination of the EPN results with other ZPD solutions. This covers intra-technique comparisons, i.e. with results from other GNSS solutions like IGS or near real-time processing, as well as inter-technique comparisons, e.g. with results from VLBI, radiosondes, models, etc. For this purpose a new monitoring and validation tool has been developed. Written in C++ ‘TropMon’ consists of several modules for import and export of data, visualisation, data analysis such as interpolation, comparison, combination and time series analysis. Besides existing input and output formats ‘TropMon’ includes two special modules for import/export and storage of data, a mysql data base and an XML interface. Originally designed as a pure interactive tool, basic features of ‘TropMon’

will be available for batch processing in the near future.

This paper explains the basic principles of ‘TropMon’ and its various analysis options. Some results for selected stations are shown demonstrating the potential of the program.

**Keywords.** Zenith Path Delay (ZPD), EPN, mysql

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## 1 Introduction

During GNSS network processing of the EUREF Permanent Network (EPN) stations Zenith Path Delay (ZPD) parameters are estimated. Originally a by-product of the derivation of the core EPN product, the station coordinates, ZPD parameter estimation evolved to an individual product for several years now. The exchange for these parameters is carried out in the SINEX TRO format, a special SINEX-like file type originally developed by the IGS (1997). Beside the station coordinate combination, see Habrich (2009), a combination of the ZPD parameters has been established in the EPN in 2001. The input as well as the output files from the individual troposphere solutions and from the combination can be downloaded via ftp from the BKG data centre (<http://igs.bkg.bund.de>). Moreover, site-specific combined ZPD time series and site-specific ZPD bias time series for the contributing Local Analysis Centres (LACs) are displayed on the web page of the EPN CB (<http://www.epn.oma.be>).

Beyond the processing and the combination of the LAC’s troposphere solutions the comparison of the

EPN results with other ZPD solutions is an interesting task. One could think about intra-technique comparisons, i.e. with IGS results, as well as inter-technique comparisons, e.g. with results from radiosondes. Since 2008, the comparison with results from radiosondes is periodically updated for a subset of currently 99 EPN stations thanks to the Memorandum of Understanding between EUREF and EUMETSAT, Vedel (2009), and displayed on the EPN webpage as well. Other comparison, e.g. with VLBI results or with GNSS NRT results, are done manually or interactively when needed.

These drawbacks urged the question of developing a more appropriate tool especially for the station-specific analyses of ZPD parameters.

## 2 Status of EPN ZPD product

ZPD parameters of the EPN stations are estimated and combined since June 2001 (GPS week 1108). The EPN LACs deliver their processing results in daily files. The main outputs of the combination are a weekly combined TRO file and a corresponding summary file of the combination process. As an overview about the overall agreement of the individual LACs with respect to the combination the weekly mean biases for each LAC (Fig. 1) and the corresponding standard deviations (Fig. 2) are computed on request. Both figures show the continuously improved agreement of the LACs ZPD processing.

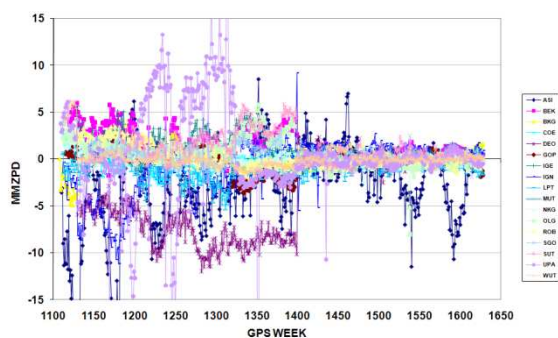


Fig. 1 Weekly mean biases (top) and the standard deviation for each LAC with respect to the EPN combined solution

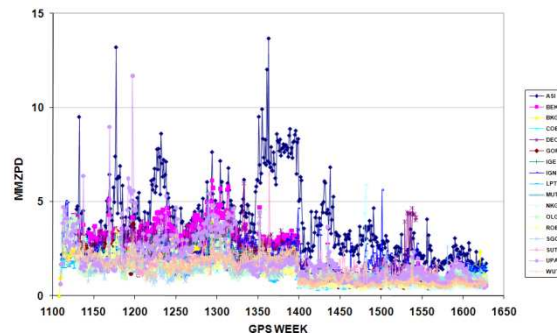


Fig. 2 Weekly mean biases (top) and the standard deviation for each LAC with respect to the EPN combined solution

The combination is carried out on a weekly basis, using a suite of Shell and Perl scripts as well as Fortran programs for the core combination. Some advantages of the existing software are:

- automated processing possible, upload and mailing thanks to file control for the routine operation;
- robust outlier detection.

However, there are also some disadvantages or restrictions of the existing software, e.g.

- only daily or weekly combination is possible, i.e. no, e.g., session-wise combination;
- additional (separate) steps for interpolation are necessary if the sampling rates or time stamps of the solutions are different;
- separate tools are necessary for inter-technique comparisons, plotting of results etc.;
- only SINEX TRO files can be processed.

## 3 Basic elements of TropMon

The “BKG Troposphere Parameter Monitoring and Validation Tool“ (TropMon) is a scientific data visualisation and analysis software with special emphasis on troposphere parameters (Fig. 3 showing the main window of current version 1.10). In addition to modules for import and export of common data formats, ‘TropMon’ includes two special modules for import/export and storage of

data from/to a mysql database and an XML interface.

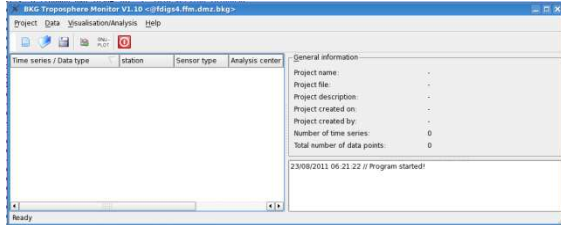


Fig. 3 Main window of the monitoring and validation tool (version V1.10)

Some basic characteristics of the tool are:

- Programming language is C++ with Qt, Qt widgets for technical applications (qwt), GNU Scientific Library (GSL); new version includes GNUplot;
- Database is mysql;
- Input and output formats currently supported are (Fig. 4): SINEX TRO, COST format, see Offiler (2003), XML, custom ASCII format, VMF1, see Boehm et al. (2006).

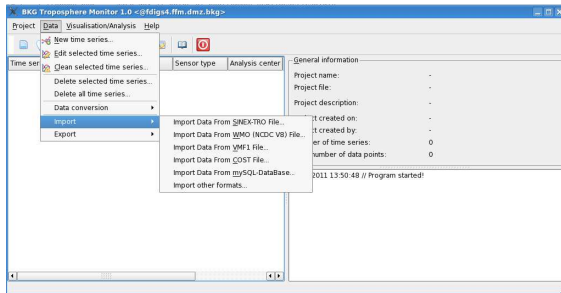


Fig. 4 Screenshot of ‘TropMon’ option data import

#### 4 Analysis tools of TropMon

‘TropMon’ is based on time series. Every type of data to be analyzed has to be stored in a time series object. For some modules, existing open-source libraries such as the GNU scientific library GSL (<http://gnu.org/software/gsl>) are used. The main features applied to ZPD or related time series are:

- interpolation of data gaps and generation of identical sampling intervals (different options possible);
- editing of time series allowing e.g. disabling or deleting of data (Fig. 5);
- comparison / differencing of different time series;
- combination of different time series (with and without weighting, different options possible, Fig. 6);
- polynomial regression including outlier detection and outlier marking;
- computation of means and biases in e.g. daily, weekly, monthly, etc. batches.

Beyond the analyses, visualisation of time series and export as separate figures (pdf or postscript) is integrated (Fig. 7).

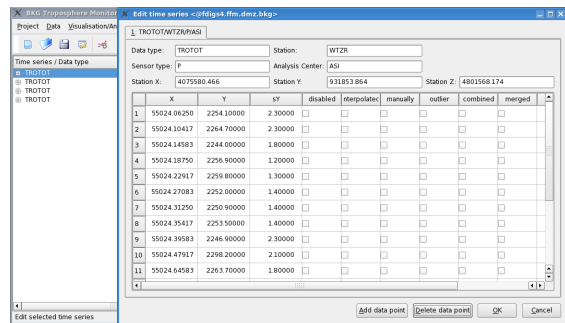


Fig. 5 Screenshot of ‘TropMon’ option editing panel with several flags for each observation

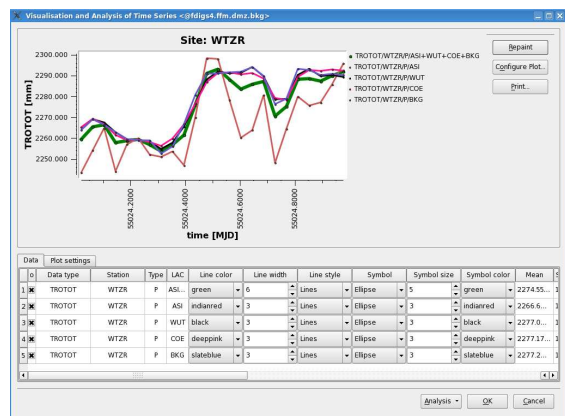


Fig. 6 Screenshot of ‘TropMon’, result of combination with four LACs, station WTZR

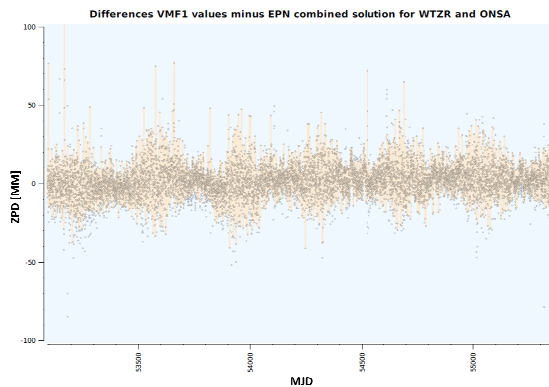


Fig. 7 Time series of ZPD differences between EPN combined solution and VMF1 model parameters for ONSA and WTZR; exported to a pdf file

## 5 Conclusions and Outlook

‘TropMon’ is a modern and user-friendly scientific analysis tool for various types of geodetic data (especially troposphere parameters).

In addition to many standard data formats and mysql access, ‘TropMon’ can read and process any kind of column-oriented ASCII format.

Interfaces to other applications developed at BKG allowing usage of the tool also for non-EPN applications and results.

‘TropMon’ was originally designed as a pure interactive tool for analyses, especially to investigate individual sites. Starting with Version 1.10, basic features of ‘TropMon’ for a no window mode are in preparation. A configuration file will be written during the interactive session which can be used in the batch processing. The file can be modified by the advanced user using a simple editor. For plotting purposes, GNUplot is used in addition to the existing routines (Fig. 8).

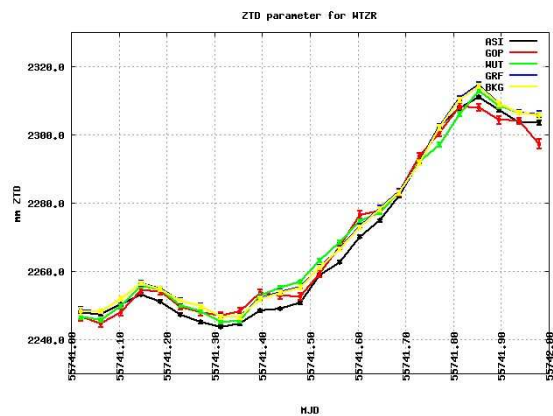


Fig. 8 Time series of ZTD parameters from different solutions for WTZR; exported to jpg file

## References

- Boehm, J, B. Werl, H. Schuh (2006). Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium-Range Weather Forecasts operational analysis data. *Journal of Geophysical Research*, 111, B02406 DOI: 10.1029/2005JB003629.
- Habrigh, H. (2009). Updated Options and New Products of EPN Analysis. In: *Report on the Symposium of the IAG Sub-commission for Europe (EUREF)*, held in London, 06-09 June 2007, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 42.
- IGS (1997). [ftp://igsceb.jpl.nasa.gov/igsceb/data/format/sinex\\_tropo.txt](ftp://igsceb.jpl.nasa.gov/igsceb/data/format/sinex_tropo.txt)
- Offiler, D. (2003). Format Specification for COST-716 Processed GPS Data, Version 2.0a – 23 September 2003
- Vedel, H. (2009). EUREF / EGVAP MoU and Status of EGVAP. In: *Report on the Symposium of the IAG Sub-commission for Europe (EUREF)*, held in London, 06-09 June 2007, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 42.