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Tropospheric Products for Near Real-Time Applications

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1 Introduction

Atmosphere monitoring is a major scientific field of investigation at the Institute of Geodesy and Geophysics (IGG, TU Vienna) which is covered by both the Satellite Geodesy and the VLBI research group. In this presentation an overview of the research which is carried out at IGG is shown. This includes the estimation of tropospheric delays from Austrian reference stations and European stations closeby (Chapter 2), hydrostatic and wet tropospheric delays on global grids and for selected sites, coefficients of the Vienna Mapping Function (VMF1), as well as analytical models like the Global Mapping Function (Chapter 3) and the Global Temperature and Pressure model (Chapter 4).

2 ZTDs from an Austrian GNSS reference network

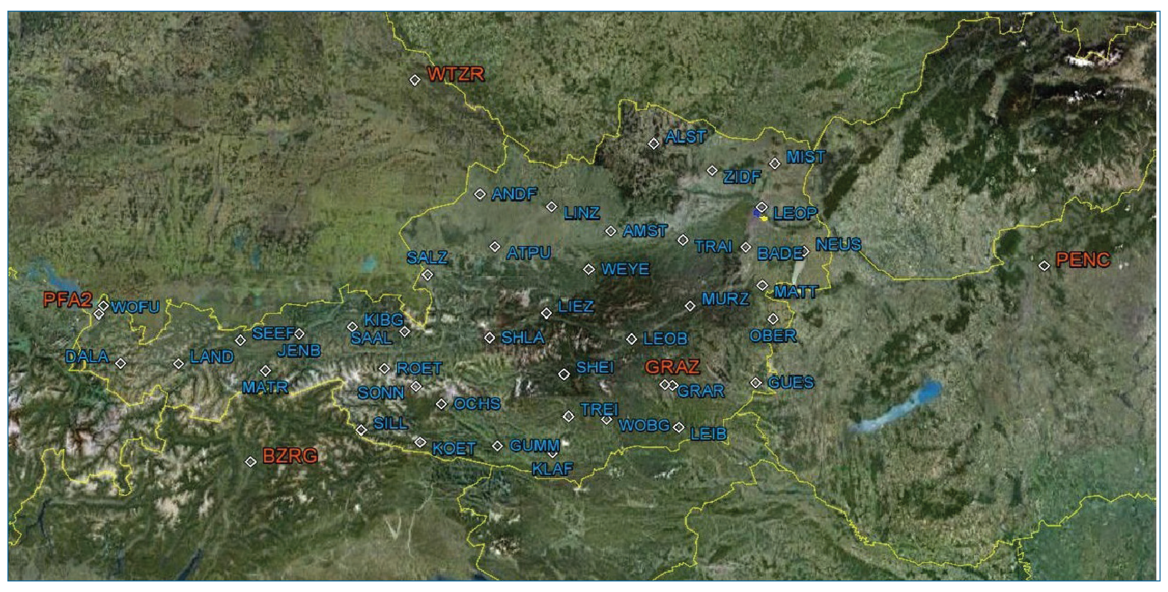

Figure 1. Distribution of the GNSS stations

Within the framework of the Project GNSSMET-AUSTRIA 2010 an automatic processing was set up which allows to estimate the tropospheric total delay in zenith direction (ZTD) over Austria in near real-time with an formal error better than 1 mm and a temporal resolution of 1 hour. This processing scheme was used to reprocess ZTDs over a time span of three month in summer 2011 and to study its impact on the numerical weather model AROME (see Chapter 2.2). Therefore GNSS observation data of 40 reference stations, distributed over the whole Austria domain are used. The GNSS stations are allocated with a horizotal distance of 30-80 kilometers and a maximum height difference of up to 2500 meters. To define the datum, observation data of five IGS stations (BZRG, GRAZ, PENC, PFA2 and WTZR) are implemented, see Figure 1. The ZTDs, based on a double difference approach, are computed by means of the BERNESE V5.0 package. In Table 1 the input data and main parameters set up in BERNESE are listed. After every day a normal equation file and in a second run a 3-day solution

Observation data	GPS/GLONASS, L1 & L2, 30 sec sampling rate
Elevation cut-off	5 degree
Orbits and ERP	IGS Final Products
Datum definition	Constraints on IGS stations (0.1 mm, ITRF2008, 2005.0)
Mapping Function	GMF, wet
Parameter Spacing	1 hour (ZTD), 1 day (Gradients)
Rel. a priori sigmas	2 mm (ZTD), 0.2 mm (Gradients)
Ambiguity Solution	Sigma-Strategie (L5/L3)
Antenna corrections	Absolute Calibration

Table 1. Processing parameter

was estimated to overcome the inconsistences at day boarder. The coordinate repeatability is better than 2 mm in the north, 2.5 mm in the east and 3.5 mm in the up component. In a final step the ZTDs and the formal error from the median day of the 3-day solution was extracted. The formal error is centered around 0.6 mm. The distribution of the formal error is shown in Figure 2. It is worth to note that the formal error does not properly account for correlations between GNSS observations.

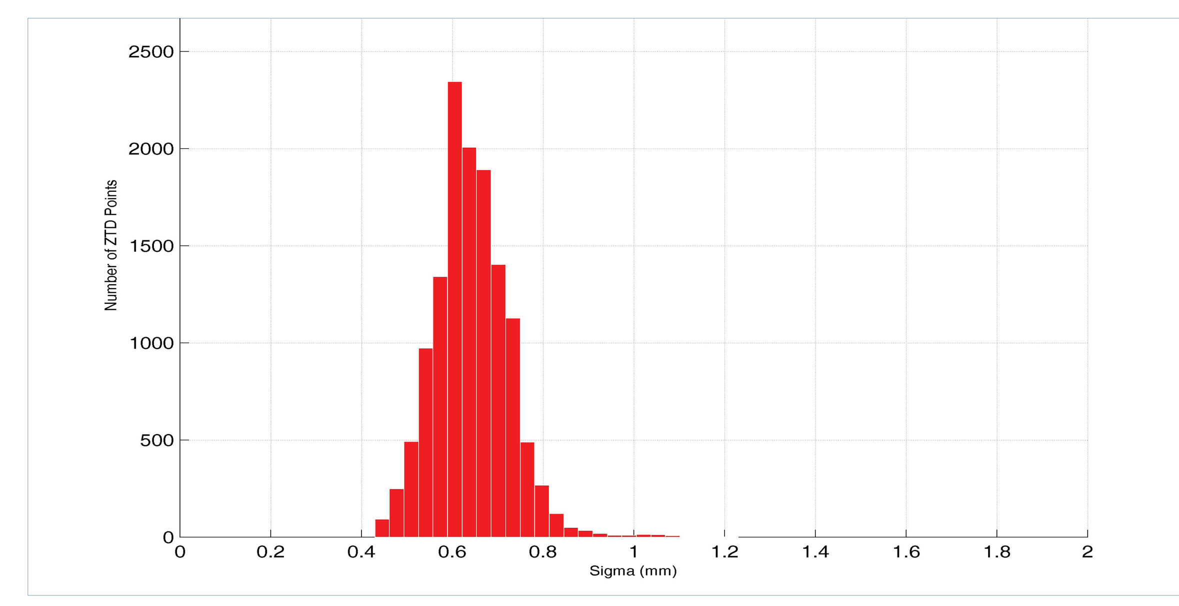

Figure 2. Histogram of the formal errors for the troposphere solution

2.1 Comparison with IGS products

The final tropospheric zenith path delays of the IGS stations mentioned in Chapter 2 are compared with the estimated ZTDs. In Figure 3 results over ten days are shown, exemplarily for the two stations BZRG and GRAZ. The correlation between the different ZTD series is in all cases larger than 95% and a bias in the range of 2 mm could be observed. However, the standard deviation of the differences is in the order of 10 mm and is quite high in comparison to the formal errors (Figure 2). In some cases the series differ by ± 25 mm. Without validation by other techniques it can not be said which series is more reliable.

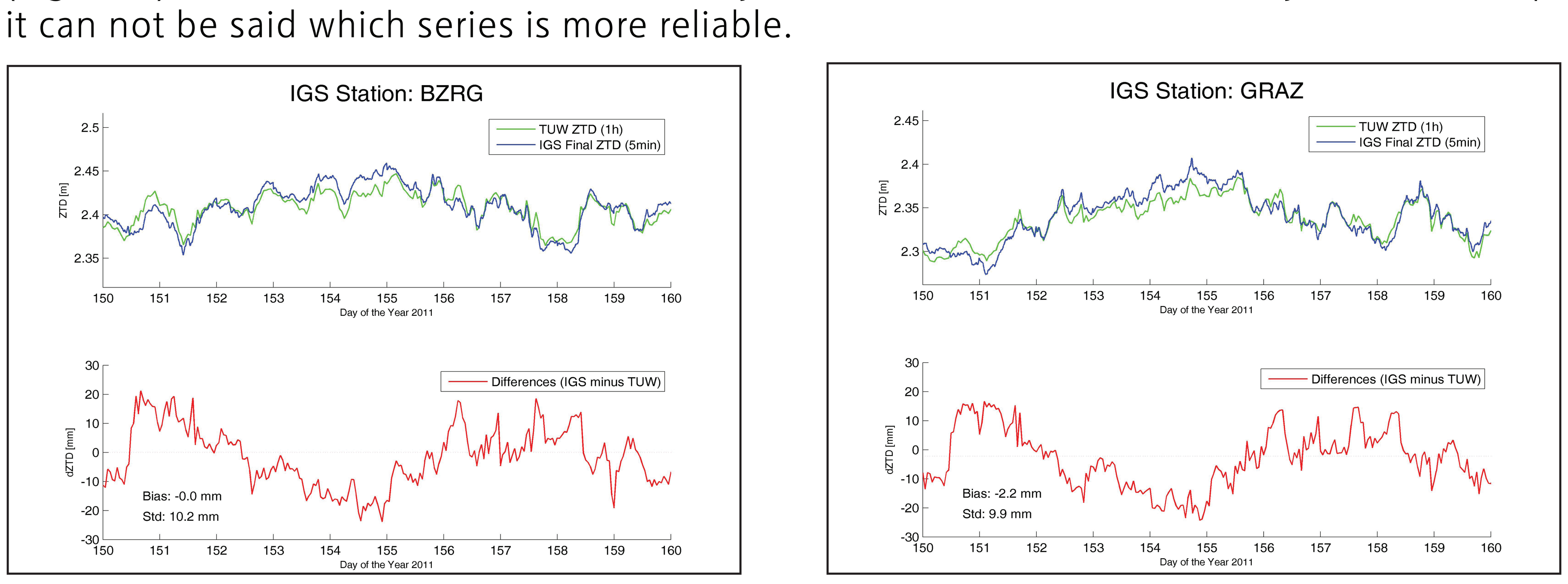

Figure 3. Comparison of the estimated ZTD with IGS products

2.2 Assimilation into weather forecast model AROME

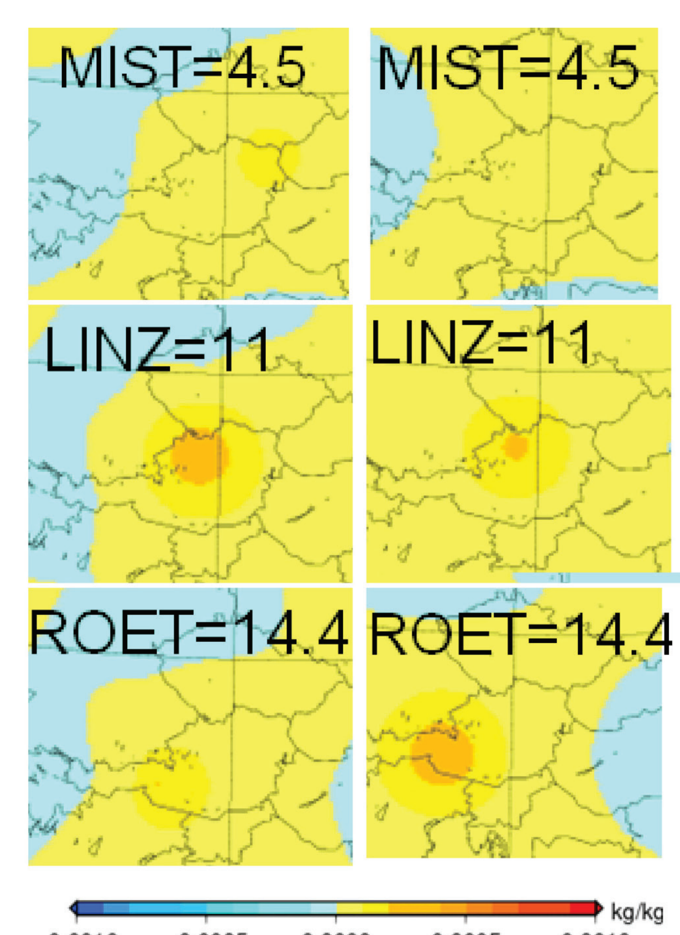

Figure 4. Estimated ZTD vs. Pseudo-ZTD

AROME (Application of Research to Operations at Mesoscale) is a non-hydrostatic numerical weather forecast model developed by Meteo France. It features a mesoscale 3DVAR data assimilation system with a horizontal resolution of 2.4 km. The AROME/3DVAR system is implemented locally by ZAMG and it runs analysis with 3 hour frequency. For data assimilation at first a so called „Obsoul files" is generated. This format allows to enter the reprocessed ZTDs (Chapter 2) into the assimilation database. Pseudo-ZTD values are calculated on basis of the parameters p_d (density of dry air), T (temperature) and e (water vapor pressure) which are predicted values from the numerical weather model. Afterwards the analysis is run with the pseudo-ZTDs and the reprocessed ZTDs. Figure 4 shows its influence on the specific humidity. Its impact to the final solution is controlled by the assigned ZTD estimation error.

3 Vienna Mapping Function (VMF1) and Global Mapping Function (GMF)

VMF1 is a mapping function which is currently providing the best accuracy. Its wet and dry coefficients are recalculated every six hours on the basis of data from the numerical weather model ECMWF. The coefficients on global grids (2.5 x 2.0 degrees) as well as the a priori wet and dry signal delays at selected sites are available since 1992 for post processing with a delay of less than 34 hours. Parameters determined from forecast data for real-time and near real-time applications are available too, but only with a lost in accuracy and with limited access (for scientific purposes only).

The GMF is an 'easy to implement' mapping function, consistency with the VMF1. Its coefficients were obtained from an expansion of the VMF1 parameters into spherical harmonics on a global grid. Input parameters are the day of the year and the station coordinates. It can be computed for any site and and time but only with deficiencies in the accuracy because the GMF takes only the seasonal

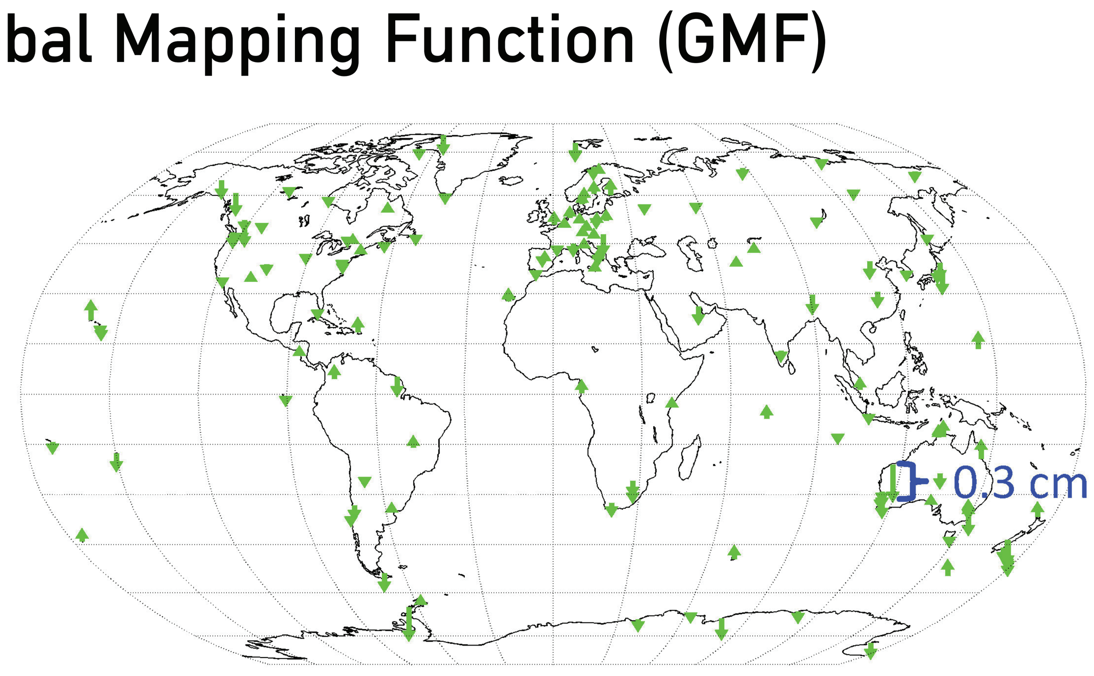

Figure 6. Differences in GPS-heights between GMF and VMF1 [Willis P., 2008]

signal into account and the daily and subdaily variations keep unmodeled. The resulting station height error for a global GPS network is shown in Figure 6. For most stations it is below 1 mm and up to 3 mm for a few stations in higher latitudes. The VMF1 grid files, time series for selected sites, fortran routines and literature are availble at the ggosatm-webpage.

4 Global Temp. & Pressure model (GPT)

The empirical GPT model provides pressure and temperature at any site at mean sea level and it takes annual variations and variations in longitude and latitude into account. Similar to the GMF, it relies on pressure and temperature profiles from ECMWF on a global grid. Its input parameters are station coordinates and the day of the year. Boehm et al. 2007a showed that in comparison to common models by Berg (1948) and Hopfield (1969) the GPT allows to describe the distribution of pressure and temperature more reliable. Improvements up to 10 hPa or even more are possible, which corresponds to a station height error of 2.4 mm. Hence it is recommended to use at least GPT for tropospheric modelling, if no in situ measurements are available.

http://ggosatm.hg.tuwien.ac.at/DELAY/

5 Outlook

At IGG a global processing strategy is currently set up which allows to estimate tropospheric delays, north and east gradients from a global GNSS network. Further we work on a method to derive a 3D humidity fields from regional GNSS reference networks for real-time and near real-time applications. This includes in a first step the estimation of double difference residuals which should be used to establish a real 3D humidity model (tomography) of the lower troposphere. In a second step this model should allow to calculate accurate range corrections which could be used in real-time application, e.g. to improve the PPP ambiguities solution.

References

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