COST ES1206: Contribution of the Vienna University of Technology

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Introduction

Atmospheric research is one of the major activities at the Research Group Advanced Geodesy. Hence we are particularly keen to be able to contribute to the European COST Action (European Cooperation in Science and Technology) ES1206 which started in May 2013 with the aim to investigate advanced GNSS tropospheric products for monitoring severe weather events and climate. We are presenting an excerpt of our research activities which are related to Working Group 1 - GNSS processing techniques. This includes the wide field from tropospheric a priori models to real time GNSS analysis.

GNSS Tomography - Expectations from Galileo FOC

GNSS observation data allow recovering the structure of the atmosphere. In particular the temporal and spatial distribution of the highly variable water vapour in the lower layers of the atmosphere (up to 12 km) is of interest for regional weather forecasting and precise positioning. In order to obtain this information the atmosphere is divided into a 3D voxel-model (see Figure 2) and the wet refractivity in each voxel is determined by applying a tomography approach as described in Notarpietro (2011). Input data are Slant Wet Delays (SWD) derived by GNSS observations.

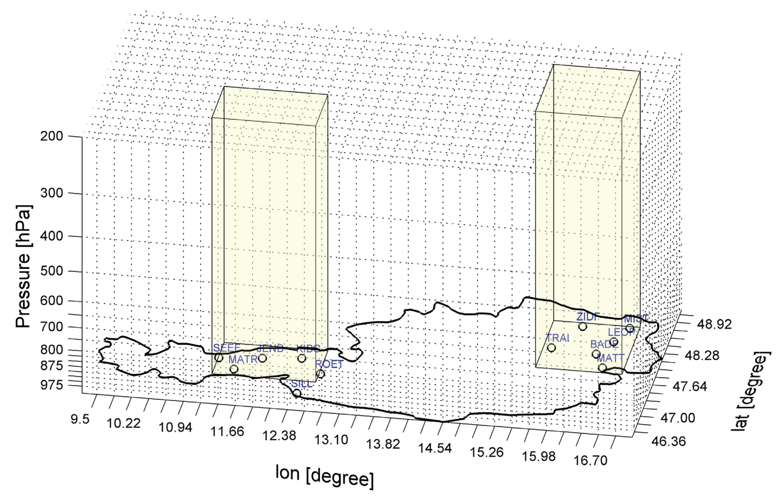

Figure 2: 3D voxel structure of the atmosphere above Austria with a spatial resolution of ~18.0 km and 16 pressure levels. A pressure value of 200 hPa corresponds to a height of about 11800 m. Each blue dot represents a GNSS reference site.

Independent from the reconstruction technique a high station density and a large number of GNSS observations are necessary to obtain an enhanced resolution (especially in vertical direction) and stable tomography results. Upcoming satellite systems like Galileo will push on the tomography approch. In order to study its impact on GNSS tomography a full operational capability (FOC) of Galileo satellites is simulated and analysed. For GPS and GLONASS the constellation that was operational in September 2013 is assumed. Figure 3 shows the lines-of-sight to be observed at a site near Vienna, Austria.

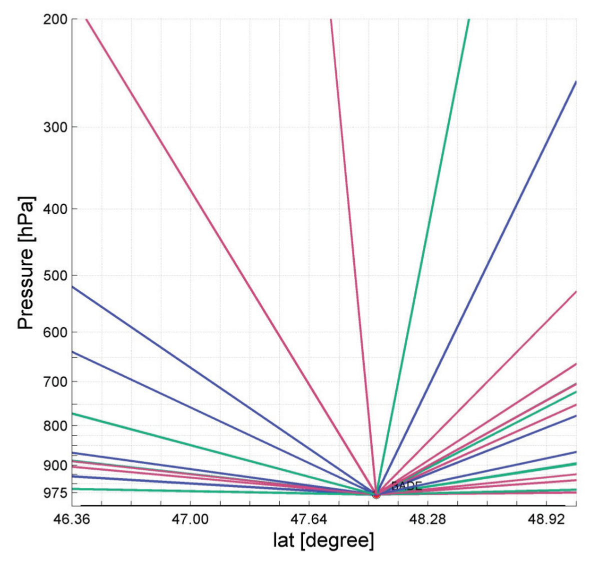

Figure 3: Lines-of-Sight to all GPS (red line), GLONASS (green line) and Galileo (blue line) satellites in view at GNSS site Baden (near Vienna) - plotted for a single epoch. The directions to the satellites are calculated from broadcast ephemeris. Both, the site coordinates and the directions are input for the voxel traversal algorithm; see Amanatides and Woo (1987). This algorithm is used to detect voxel traversals and to determine the number of empty voxels (voxels which are not passed by any line-of-sight).

Galileo provides about 50% additional observations in new azimuth and elevation angles (compared to GPS+GLONASS). Thus the distribution of slant path delays, especially the horizontal coverage, becomes more homogeneous and the number of empty voxels can be significantly reduced. We analysed the observation of all three satellite systems and found that after 15 minutes in average 50% of the voxels remain empty if only GPS observations are used. If GLONASS and Galileo observations are added, the number of empty voxels can be reduced by 35% and its temporal variation (due to the changing number of satellites in view over time) is widely compensated.

In further consequence the tomography approach will benefit from these additional data and its solution will become more stable. In our cooperative project GNSS-ATom we continue our studies in order to find the „best" approach to obtain SWD (differenced / undifferenced) from GNSS observations, to reconstruct N_{wet} from SWD and to assimilate it into high-resolution weather models.

Real Time GNSS processing

Recently the work on the project PPP Serve has been finished. Within the framework of the project we developed a real time capable software for the estimation of so-called satellite-phase-biases which allow for integer ambiguity resolution in PPP. The processing scheme of the software also includes the estimation of the ZTD at every station of a chosen network. Currently our model uses the Niell MF, that considers different obliquity factors for the wet and dry components. The wet tropospheric delay is estimated on top of an a priori model as a random walk process within a Kalman filter together with the other parameters. First comparisons between our ZTDs, estimated within the fixed PPP solution, with the ZTDs of a network solution indicated a very good agreement at the few millimeter-level.

Acknowledgments

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Post Processing / A priori model

Near Real Time

Real Time

Tropospheric error correction models GPT2(w)

In 2013 two updates to the Global Mapping Function (GMF) and the Global Pressure and Temperature model (GPT) have been released which are called GPT2 and GPT2w. Input parameters are just the date and the station coordinates (longitude, latitude and ellipsoidal height). GPT2 provides pressure, temperature, water vapour pressure, temperature lapse rate and mapping function coefficients on 5 degree grids as average values, annual and semi-annual variations. Therewith it is possible to calculate the zenith hydrostatic (ZHD) and wet delay (ZWD) and the mapping function for any receiver on earth at any time.

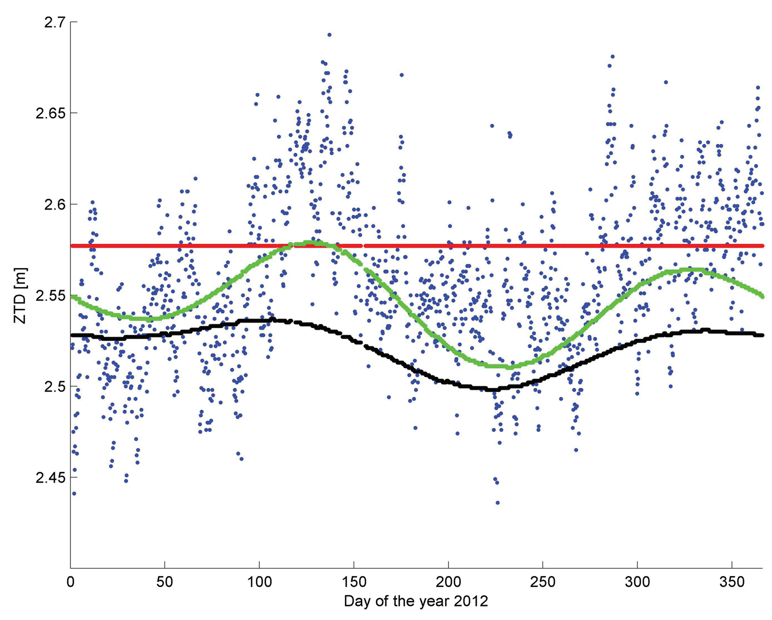

Figure 1: Tropospheric delay in Zenith direction (ZTD) at GNSS site Malindi (Kenya, Africa) delivered by CDDIS / IGS (blue), the tropospheric delay model RTCA MOPS (red), GPT2 (black) and GPT2w (green). The ZTD course is dominated by semi-annual periods. GPT2w benefits from the new parameters and the improved wet delay model.

The extension ‚w' in GPT2w is related to the additional parameters water vapour decrease factor and mean temperature which are provided on 1 degree grids in order to calculate the zenith tropospheric delay (ZWD) more reliably. The positive impact of the new parameters and the improved wet delay model is seen in the comparison with ZTDs provided by IGS in 2012 (see Figure 1). The bias and RMS could be reduced significantly - especially in comparison to common troposphere models for Satellite-based Augmentation Systems (SBAS) like RTCA MOPS.

Model	Bias (cm)	RMS (cm)
GPT2w	-0.03	4.13
GPT2	-0.37	5.05
RTCA MOPS	-2.60	6.39

Table 1: Bias and standard deviation of the differences between ZTDs delivered by CDDIS (IGS) and the three blind models RTCA MOPS, GPT2 and GPT2w - calculated for 320 GNSS sites over the period 2012.

GNSS analysis for NRT ZTDs

The aim is to set up an automatic processing to estimate the tropospheric total delay in zenith direction (ZTD) over Austria in near real-time (NRT) with an formal error better than 2 mm and a temporal resolution of 15 min. The processing scheme was developed within the framework of the Project GNSSMET-AUSTRIA in 2010 and was used again to reprocess ZTDs over a time span of three month in summer 2011 in order to study its impact on the numerical weather model AROME. Now we are going to apply the processing scheme to 90 GNSS sites mostly situated in Austria and some in neighbouring countries; see Figure 4.

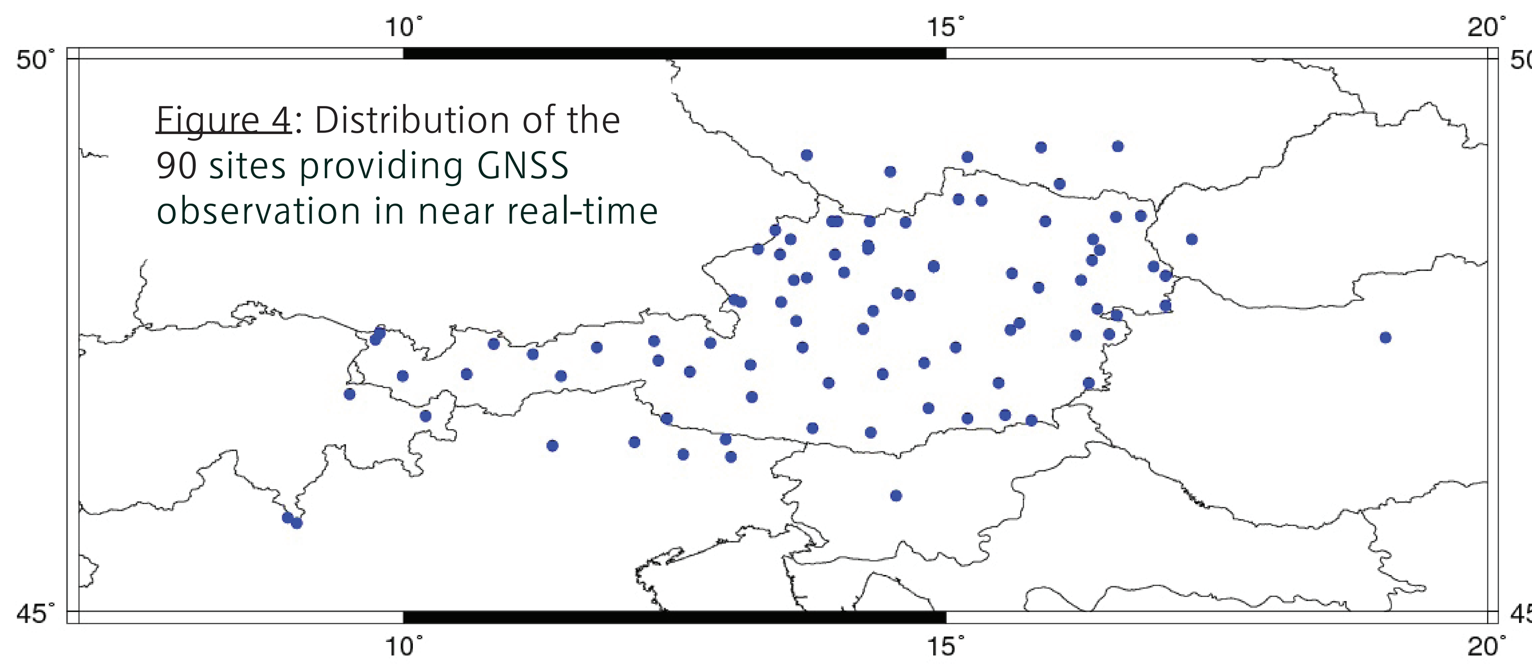

Figure 4: Distribution of the 90 sites providing GNSS observation in near real-time

The GNSS sites are allocated with a horizontal distance of 5-80 kilometres and a maximum height difference of up to 2200 meters. To define the datum, observation data of adjacent IGS and EUREF sites are implemented. The ZTDs, based on a double difference approach, are computed by means of the BERNESE V5.2 package. In Table 2 the input data and main parameters set up in BERNESE are listed.

Observation data	GPS/GLONASS, L1 & L2, 30 sec sampling rate, 7 degree cut-off
Orbits and ERP	IGS Ultra Rapid Products
Datum definition	Constraints on IGS & EUREF sites (0.1 mm, ITRF2008, 2005.0)
A priori model & MF	GPT and wet GMF
Parameter Spacing	15 min (ZTD), 12 hours (Gradients)
Rel. a priori sigmas	2 mm (ZTD), 0.2 mm (Gradients)
Ambiguity Solution	Sigma-Strategie (L5/L3), L1/L2

Table 2: Processing parameters

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