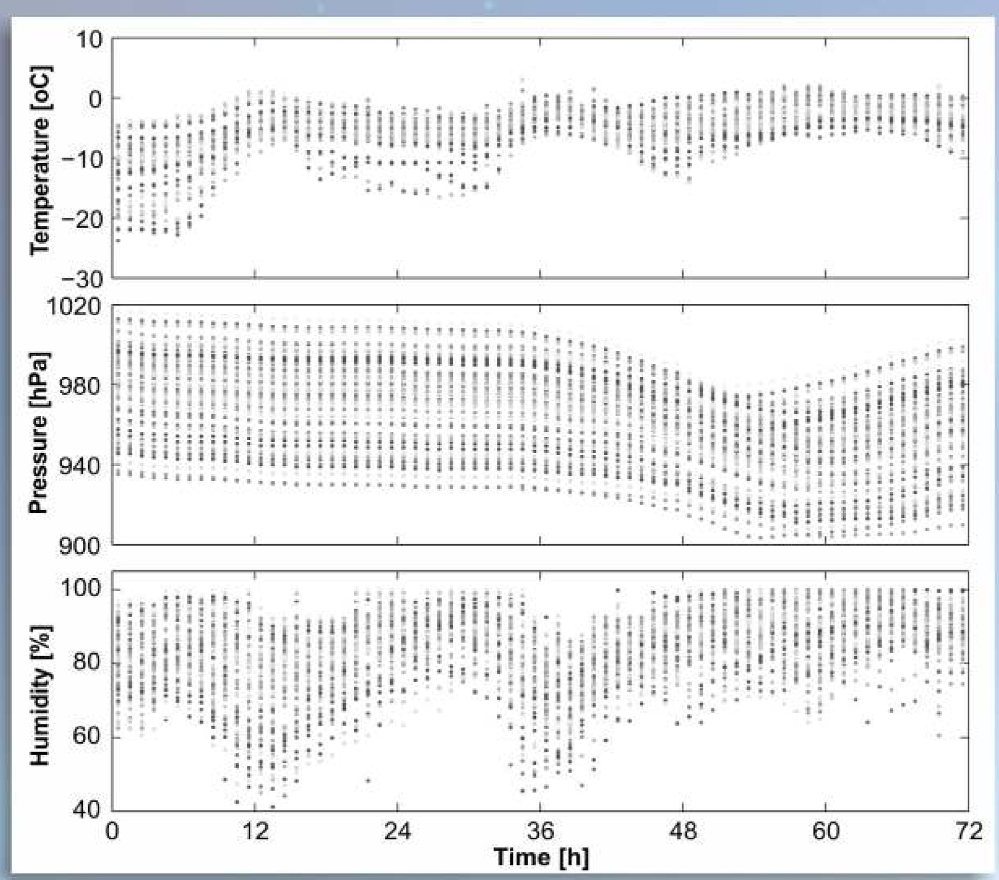
Regional troposphere models application into GNSS Precise Point Positioning technique

Tomasz Hadaś, Jan Kapłon, Jarosław Bosy, Jan Sierny, Karina Wilgan
Wroclaw University of Environmental and Life Sciences, Institute of Geodesy and Geoinformatics

INTRODUCTION

Precise Point Positioning (PPP) is a positioning technique of single GNSS receiver which applies high quality products from permanent GNSS observations to utilize the computational potential of global network analysis. Estimated satellites orbits and their clock corrections are introduced into equation system as known parameters. Dual frequency data allows computing L3 linear combination, which is free of first-order ionospheric delay, but loses the integer nature of ambiguities. Autonomous positioning requires providing a-priori information from deterministic models. To reduce the number of unknown parameters or speed up the estimation process, models should be as good as possible or even considered to be error-free. One of the main problem is tropospheric delay modeling. Application of standard atmosphere parameters or global models, such as GPT or UNB3, may not be sufficient enough, especially when positioning in unusual weather conditions. The evolution of tropospheric delay model consist of increasing temporal and spatial resolution and the transition from standard atmosphere models to models of atmosphere parameters distribution. Those can be derived from meteorological stations networks as well as from numerical weather forecast models. The improvement in positioning is that tropospheric delays will be calculated directly from observation instead of from deterministic models. The paper presents the application of two regional troposphere models being developed in Institute of Geodesy and Geoinformatics (Kaplon J. et. al. The high resolution troposphere model on the area of GBAS system) into GNSS PPP.

ZTD MODELS VERIFICATION



To reliably verify the functionality of various ZTD models, three days from 13 to 15 January 2012 (DOY 044-045) has been chosen, due to the specific weather conditions those days. There was a significant warming at the beginning of chosen period, that reaches even 15 degrees Celsius on some of the stations. In the second part there is an atmospheric front, causing high changes (20 hPa) in pressure over the area of Poland.
Both developed models have been compared to final ZTD results derived from the control solution of ASG-EUPOS conducted by the Military University of Technology Analysis Centre in Warsaw (MUTAC).

Fig. 1. Weather conditions (temperature, pressure, relative humidity) on ASG-EUPOS stations over DOY 044-046, 2012

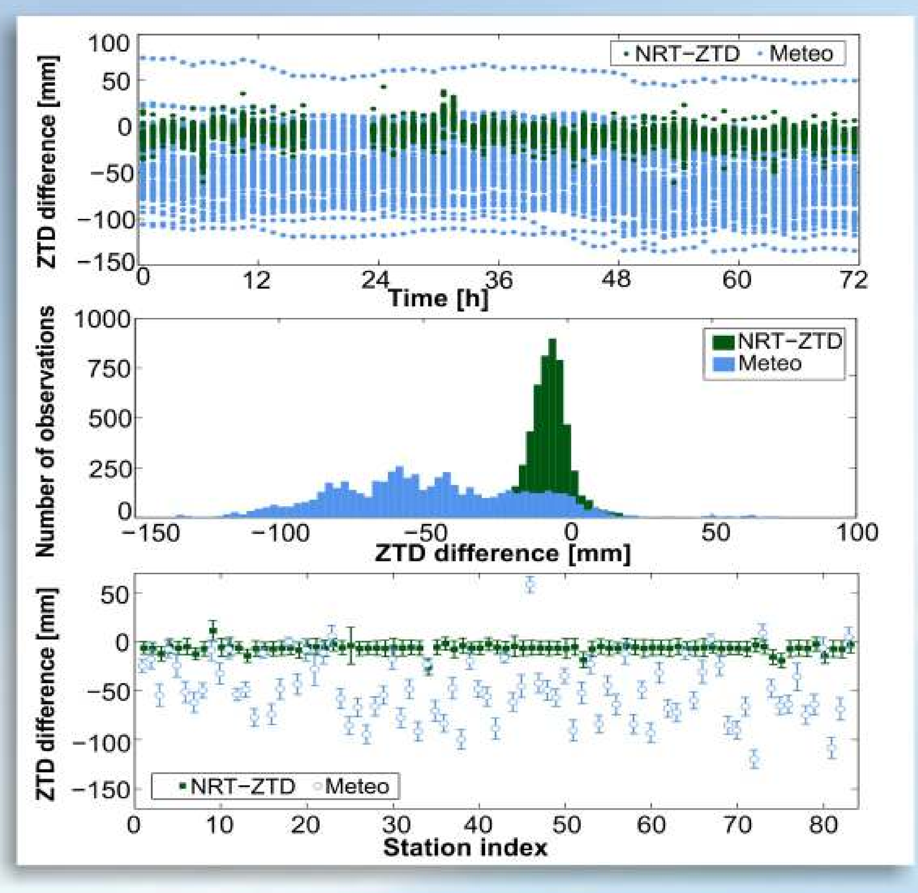


Fig. 2. Comparison of determined models with ASG-EUPOS network daily solution from MUT AC: a) differences b) histogram c) error bar.

The ZTD GNSS model may be assumed as comparable to the rapid post-processing results coming from MUT AC. Estimated value of shift (–6.2 mm) is within the boundaries of standard deviation (±8.8 mm) of its estimation. All introduced data including IGS products should be verified in future to improve processing stability, single epoch outliers should be detected and removed.
The meteorological based ZTD model requires further improvements. Various ZTD shifts for each station indicates that the interpolation procedure used is not effective enough. Calibration of individual sensors is probably required also.

PPP IN POST-PROCESSING MODE

Using the Bernese GPS Software 5.0 PPP was performed in kinematic mode, every 30 seconds in 1 hour sessions for all ASG-EUPOS stations. Calculations were made in 5 scenarios described in table:

	a-priori atm.	ZTD model	correction
No model	none	none	no
Saastamoinen	standard atm.	Saastamoinen	no
Estimated	standard atm.	Saastamoinen	yes
NRT-ZTD	None	GNSS (NRT)	no
Meteo	meteor. sensors	Saastamoinen	no

Resulting coordinates have been compared with stations true IGS08 coordinates transformed into the same reference frame and epoch. The biggest differences occurs in Up component, which is highly dependent on tropospheric delay. There is no influence of atmosphere conditions on coordinates accuracy in case of solutions with introduced regional troposphere models, while application of standard atmosphere parameters may lead to systematic errors.

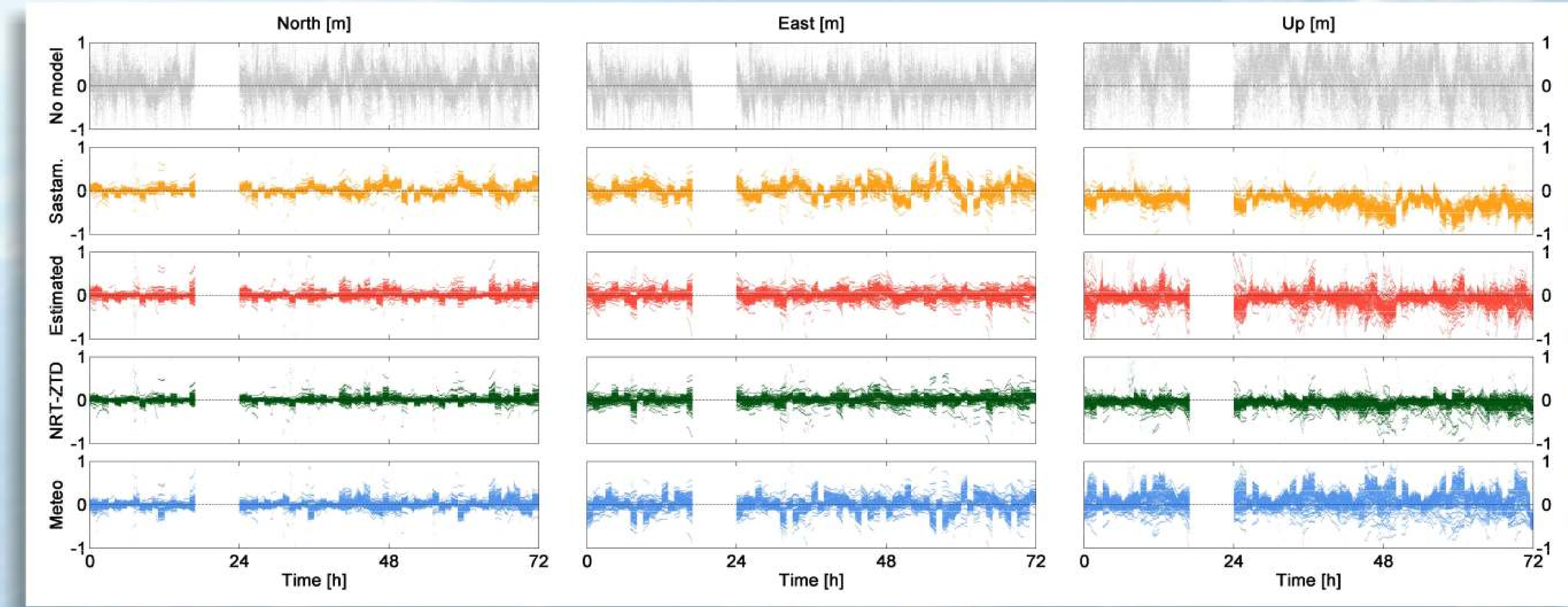


Fig. 3. Position residuals of post-processing scenarios for all stations in all epochs

PPP IN REAL-TIME MODE

Kinematic positions every 30 seconds were calculated in simulated real-time conditions in PPP mode in 1 hour sessions using GPSTools for 10 selected ASG-EUPOS stations (5 with meteorological sensors and 5 with interpolated data). The same scenarios were tested (excluding the first one neglecting troposphere delay). For stations equipped with meteorological sensor, the use of any regional model result in faster convergence time, good precision and accuracy. Faultily interpolated meteorological parameters lead to poor quality solution.

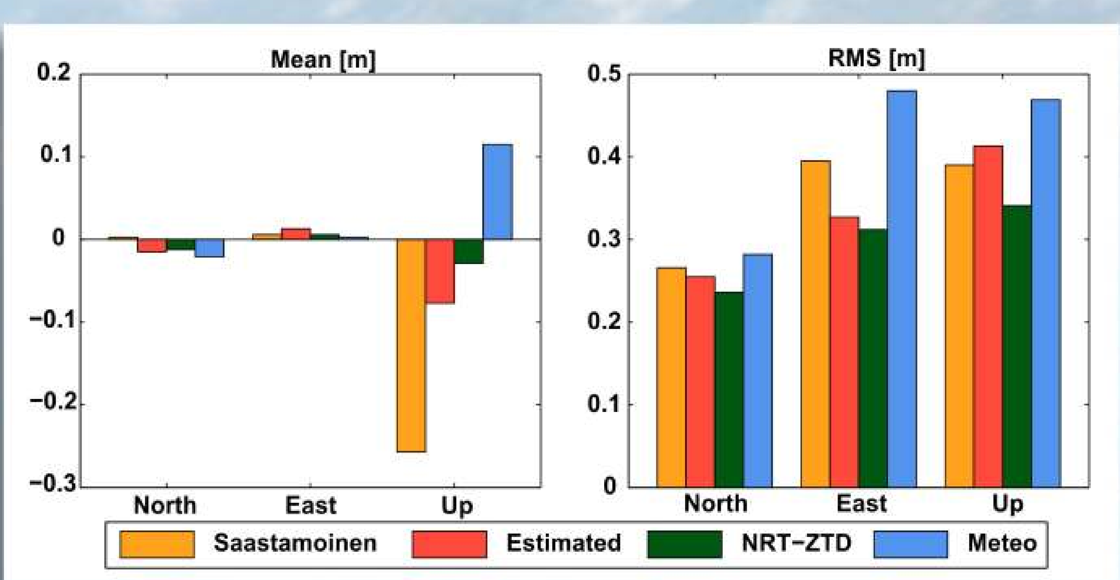


Fig. 4. Results statistics of real-time kinematic PPP in various scenarios of ZTD determination

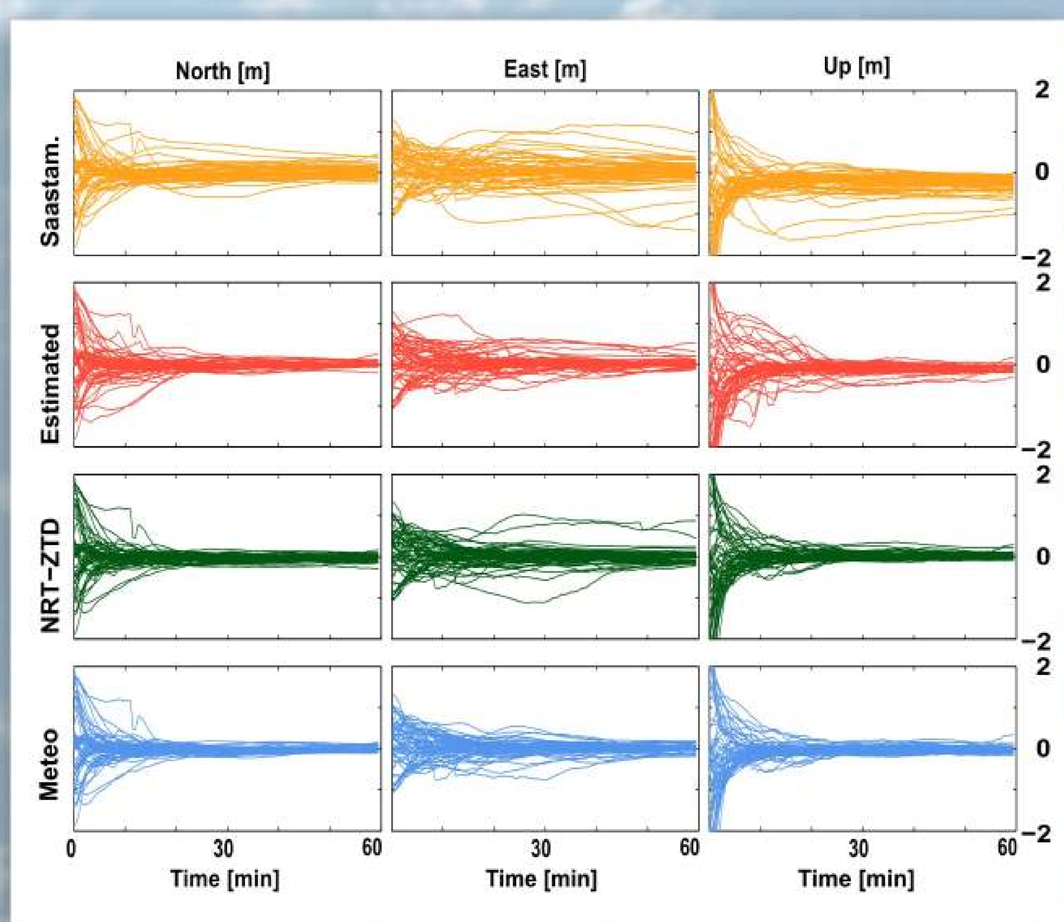


Fig. 5. Coordinate residuals for station WROC in various scenarios of real-time kinematic PPP

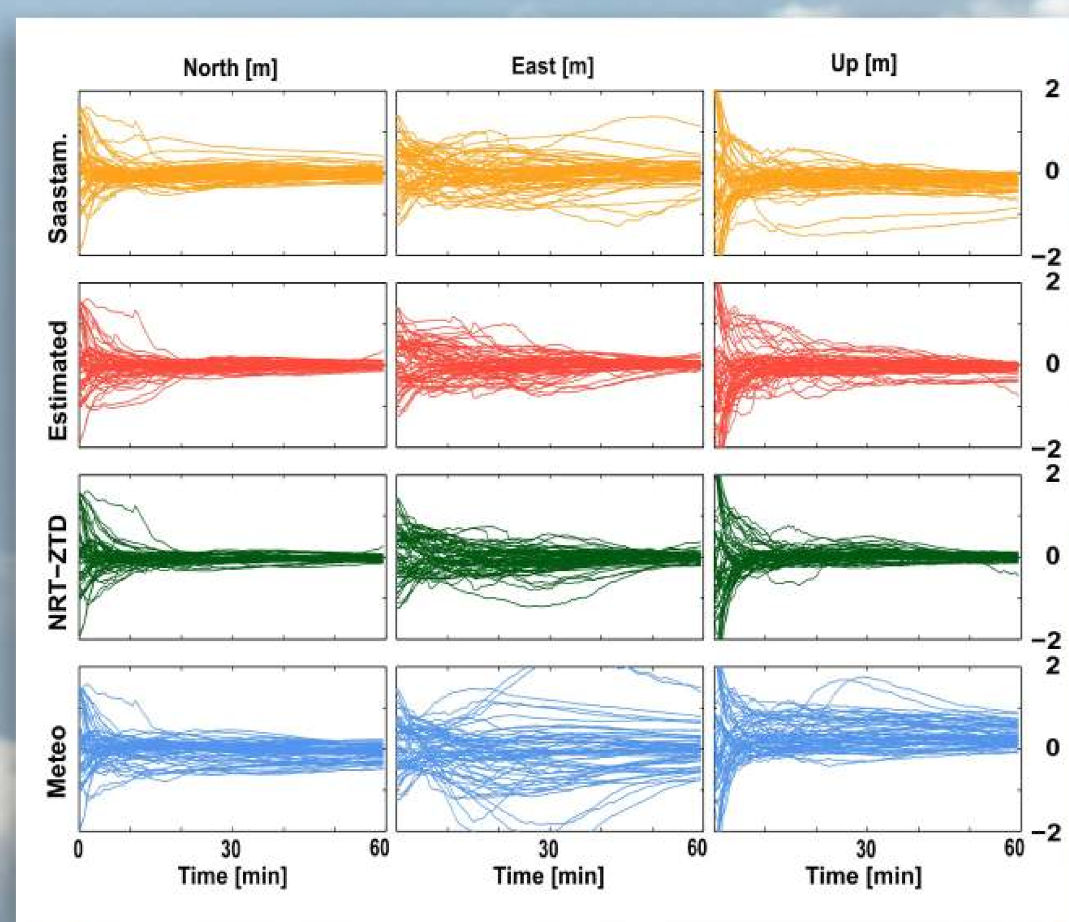


Fig. 6. Coordinate residuals for station LEGN in various scenarios of real-time kinematic PPP

CONCLUSIONS

Application of ZTD model into PPP solution allows to access the quality of developed regional troposphere models. For real-time purposes, both regional models required internal verification procedures. Meteorological based model require further improvement of meteorological parameters interpolation. Until now, both regional troposphere models are developed independently, but to obtain fully functional and reliable ZTD model, both should be integrated, so that GNSS and meteorological data supply each other. Application of ZTD model has positive effect on positioning precision and accuracy, also reduce the convergence time. Consistency of regional NRT-ZTD model with MUT AC and IGS solutions gives good opportunity to establish the future service providing in real-time short-term predictions of ZTD's utilized as a-priori values for RTK/RTN and PPP-RTK solutions.

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