Tropospheric delay constraining in real-time GNSS Precise Point Positioning

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Abstract

A common procedure in Precise Point Positioning (PPP) is to have the adjustment model accounting for the correction to an a priori value of the troposphere delay given at the first epoch of data processing, and the delay filter is updated epoch by epoch. This approach requires some time so that a change in constellation geometry allows to efficiently de-correlate among tropospheric delay, receiver clock error and height. Empirical tropospheric state models and mapping functions are available, however they may not reflect properly the actual state of the troposphere, especially in severe weather conditions. In this case, it would be more appropriate to make use of a regional troposphere model based on real-time or near-real time (NRT) measurements. In this paper we propose a method of constraining tropospheric delay using external information coming from NRT analysis of the Polish GBAS network. The NRT troposphere model is combined with Vienna Mapping Functions to take advantage also from low elevation GNSS satellites. The real-time PPP processing of data from Polish EPN station was performed in one week period (DOY 113 – 119, 2014), that reflects various weather conditions (see Fig .1).

1. GNSS-WARP software

All numerical test are performed using in house developed GNSS-WARP (Wroclaw Algorithms for Real-Time Positioning) Software using IGS Real-Time Service (RTS) products. Currently the software is enabled to process GPS and GLONASS data (other constellations can be easily included), both in real-time and post-processing mode (the second one simulates the real-time conditions) for static and kinematic data. It was significantly developed during the COST-STSM-ES1206 mission at University of New Brunswick (UNB). Its performance was verified by comparing the results with the ones derived from UNB PPP software GAPS (GPS Analysis and Positioning Software).

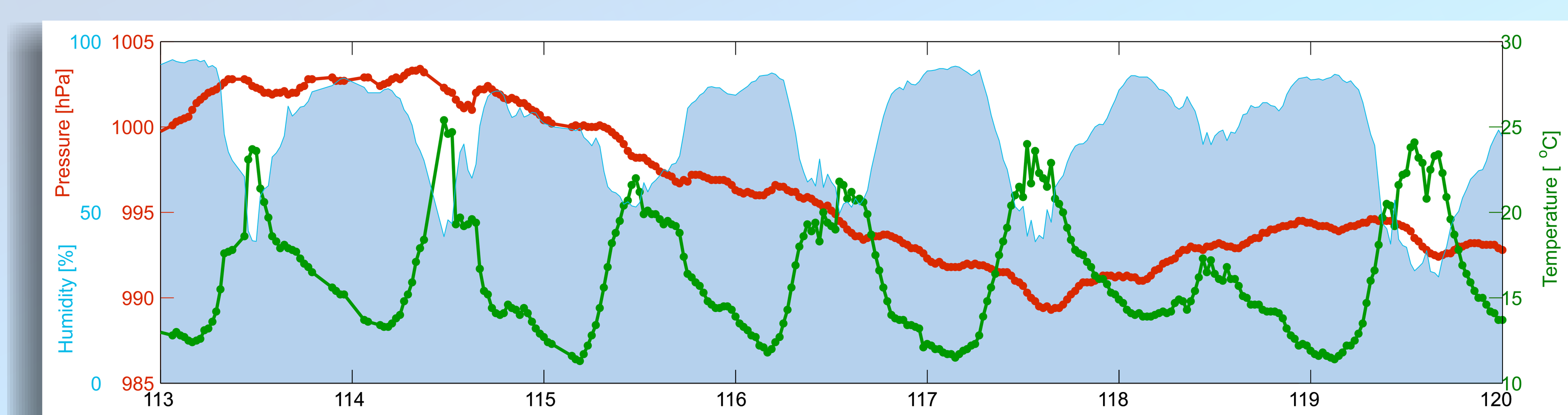

Fig. 1. Values of atmospheric parameters during the time of experiment (DOY 113 – 119, 2014)

2. Near real-time ZTD model

The NRT ZTD estimation service is organized to monitor the state of troposphere from GPS observations for the area of Poland from the GNSS data obtained from ASG-EUPOS CORS network (~120 stations, see Fig. 2). ZTDs is are being estimated in using Bernese GPS Software 5.0 using based on double-differenced solution with L5/L3 strategy. The quality estimated with respect to the EPN final combined troposphere product and ASG-EUPOS rapid solutions is 8 mm of standard deviation of ZTD differences with average bias of -1.8 mm.

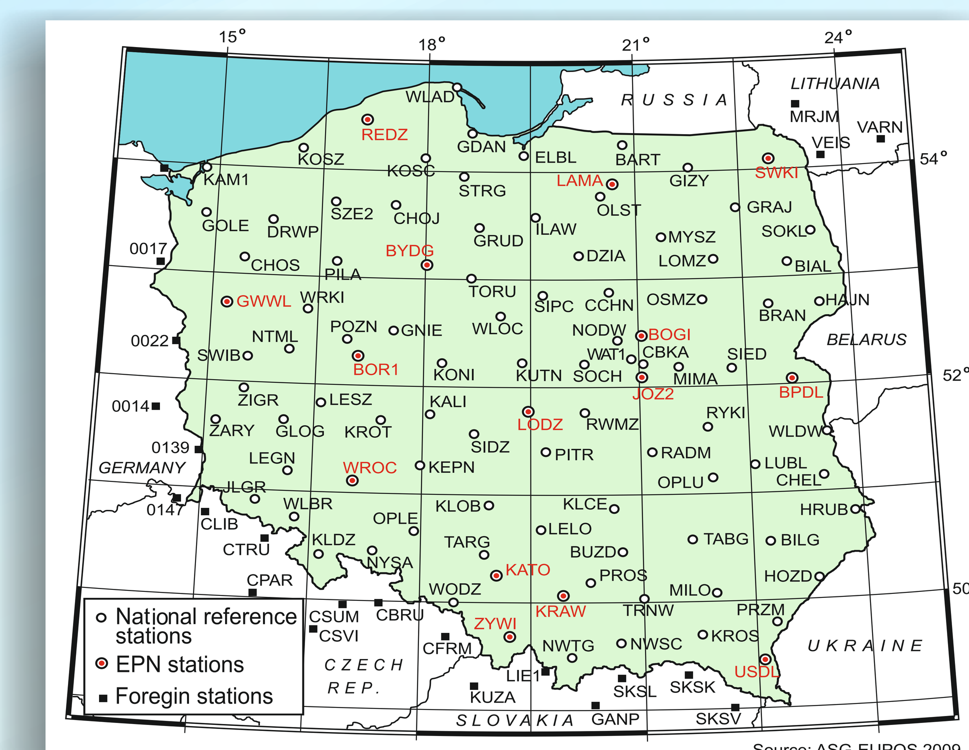

Fig. 2. Location of stations from ASG-EUPOS CORS network.

3. Unconstrained PPP solution

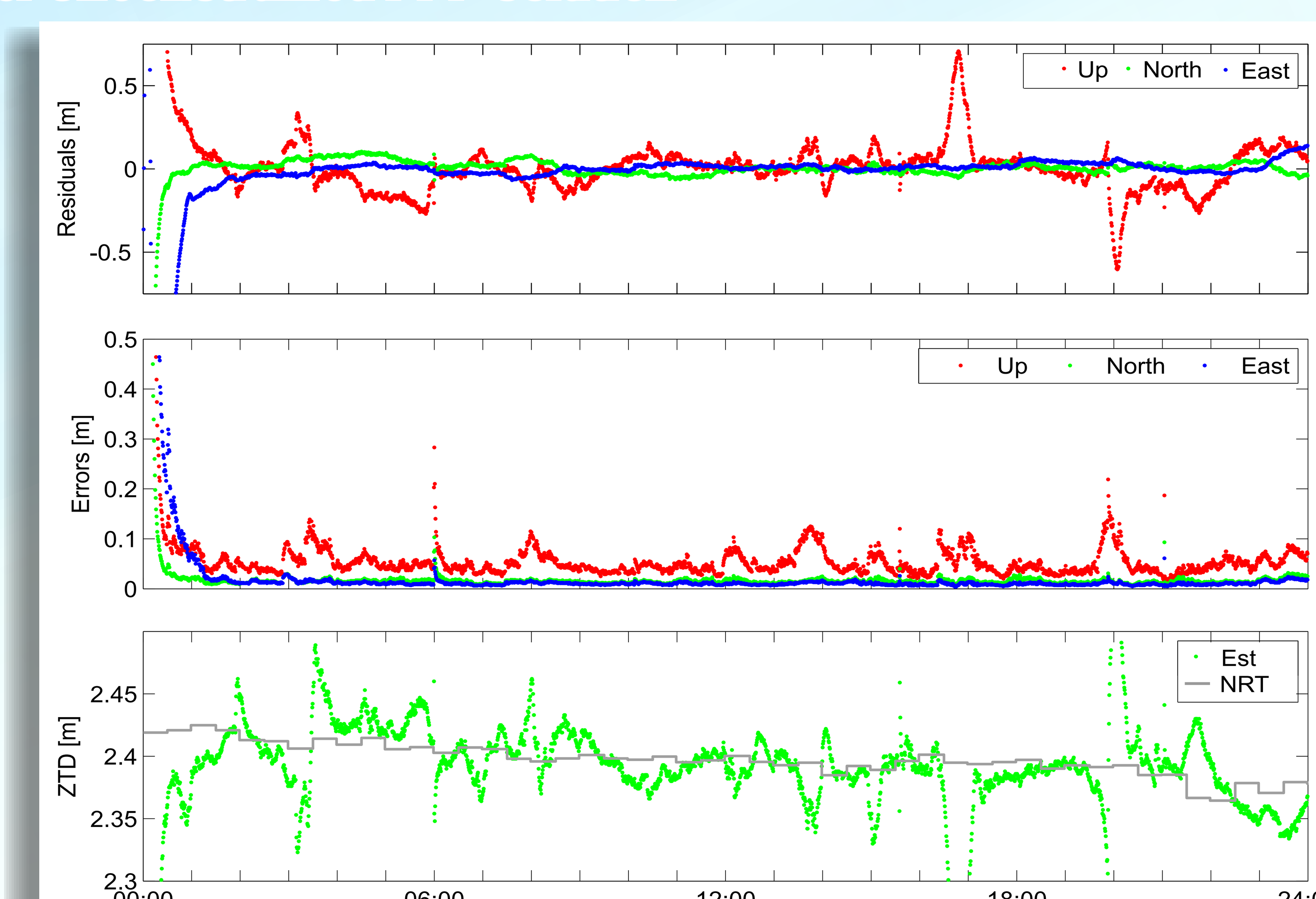

Fig. 3. Results of unconstrained kinematic PPP solution for station WROC, DOY 116, 2014

Kinematic processing of 0.1Hz GPS data using IGS RTS orbits and clocks gives accurate and precise horizontal coordinates. North and East residuals are below 10cm after the convergence time that is usually between 1 to 2 hours. The Up component is not as well determined, sensitive to number of satellites and highly correlated with estimated troposphere delay. In extreme cases, the residuals are larger than 0.7m, and the error exceeds 20cm. Additionally, some cases were observed when the quality of the solution suddenly got slightly worse for all station simultaneously (see Fig. 3., around 6 AM), that is probably related with the unexpected jump in RTS clock value of a single satellite.

4. Constraining ZTD with near real-time model

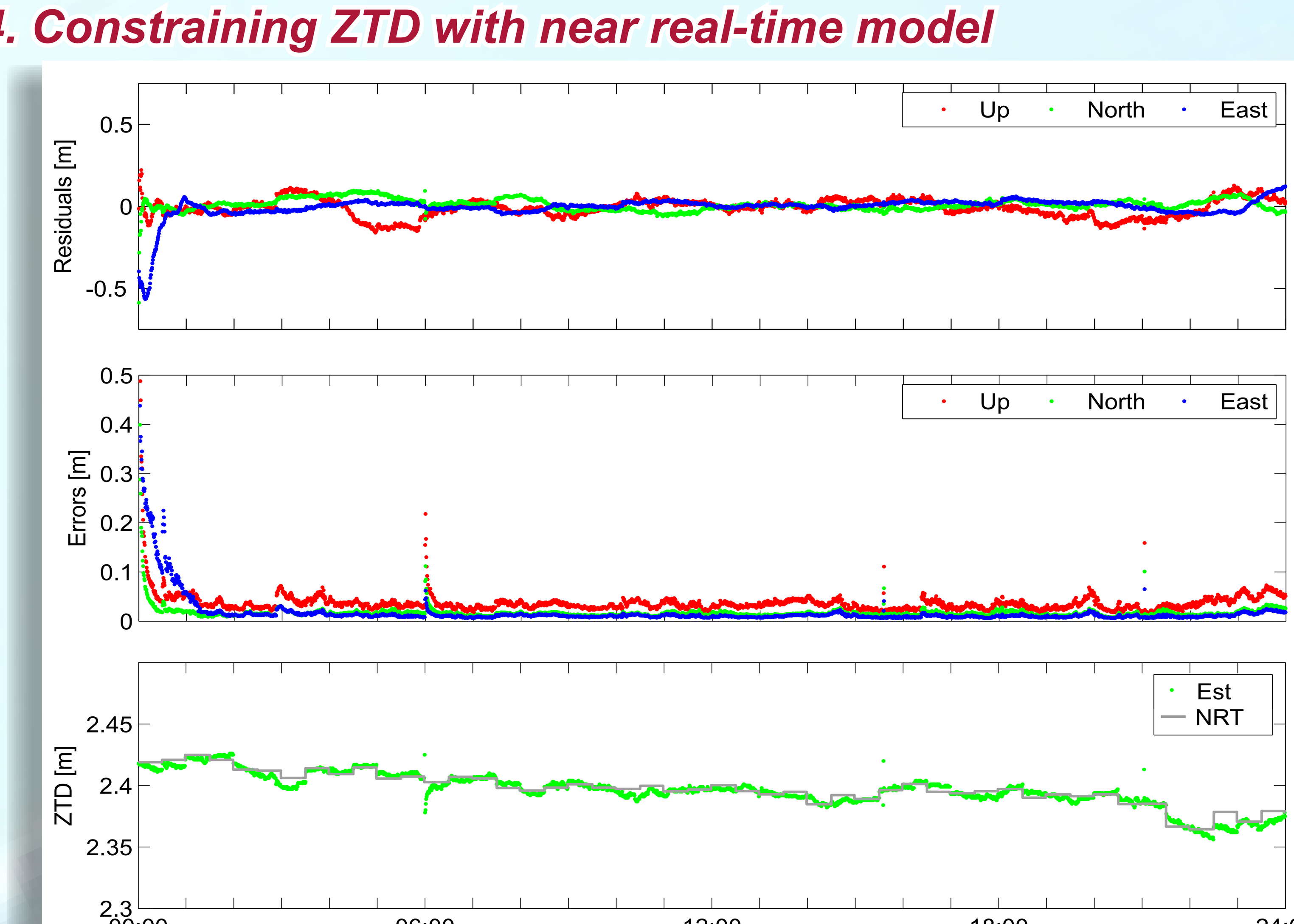

Fig. 4. Results of NRT-ZTD constrained kinematic PPP solution for station WROC, DOY 116, 2014

Because the estimated troposphere delay is very unstable and differs from the reference NRT-ZTD solution even for a few centimeters, the idea is to constrain the estimated ZTD by the last result coming from the near real-time processing. In contrast to the previous solution, in this case all three coordinates are accurate and precise, although the error of Up component (5cm on average) is still slightly larger than the error of East and North component (2cm on average). After the solution converged, the height residuals does not exceed 20cm, and are smaller than 15cm for 91% of time. From the very beginning of the data processing, the residuals for all three coordinates are much smaller, even though the estimated error is relatively large. The common cases of sudden degradation of the solution are still present.

Fig. 5. Statistics (mean bias and standard deviation) of residuals for processed EPN stations over entire testing period (DOY 113-119, 2014) using unconstrained (red) and NRT-ZTD constrained (green) approach.

5. Conclusions

After processing the 7 days long data from 13 Polish EPN station in PPP kinematic mode, in unconstrained and constrained approach, the mean bias and standard deviation of coordinate residuals (with respect to known EPN coordinates) were calculated. In both approach the results for North and East component are very similar. Only for stations KATO, the constrained approach is more precise. The NRT-ZTD model shifts the height solution by about 1cm and at the same time stabilize the solution over time. The standard deviation for all station is reduced on average by 40%, from 14cm to 8 cm. The results confirm the usefulness of near-real time troposphere delay models in real-time PPP kinematic processing and a significant improvement should be noticed in unusual or severe weather conditions.

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