Troposphere support service for real-time Precise Point Positioning

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INTRODUCTION

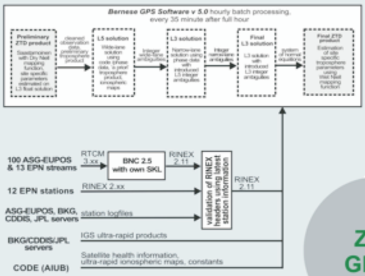
One of the open problem in real-time Precise Point Positioning is troposphere delay modeling. Troposphere delay empirical models are functions of meteorological parameters (temperature, pressure and humidity). They determine zenith troposphere delay (ZTD), which is then mapped into slant troposphere delay (STD) using respective mapping functions. 90% of refractivity is caused by the neutral hydrostatic atmosphere, while the remaining 10% depends on water vapor 3D distribution and therefore is hard to calculate. In the post-processing mode, the introduced a-priori model can be corrected during the data processing, when determining position of autonomous receiver in real-time, the high-accuracy ZTD model is expected. Application of standard atmosphere parameters or global models, such as GPT (global pressure/temperature) model or UNB3 (University of New Brunswick, version 3) model, may not be sufficient enough, especially when positioning in non-standard weather conditions. The foundation for supporting real-time positioning are regional GBAS networks. To provide fully operational service for PPP support, it is necessary to have ZTD in real-time.

Continuous GNSS observations allows to compute ZTD in near real-time regime. Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Poland provides ZTD estimates with 1 hour interval for the territory of Poland. The GNSS data is acquired from over 100 stations included in GBAS network called ASG-EUPOS. Simultaneously, meteorological observation data are collected from five different networks: EUREF Permanent Network (EPN), ASG - EUPOS stations, synoptic meteorological stations (SYNOP), airport meteorological stations (METAR) and civil network of meteorological stations (CWOP). Main issues with such data set are its inhomogeneity, unknown accuracy and instability. This causes a necessity of spatial and temporal interpolation of parameters and subsequently finding appropriate methods of verification. On the basis of collected atmosphere parameters the ZTD is computed independently.Both developed models can be used for cross-validation. Additional, independent validation is performed by the Numerical Weather Prediction (NWP) model, e.g. COAMPS. Until now, regional troposphere models are being developed independently, but to obtain fully functional and reliable ZTD model, both should be integrated, so that GNSS and meteorological data are assimilated together.

ZTD GNSS MODEL: IGGHZ-G

Since 2008 in the territory of Poland a Ground Base Augmentation System called ASG-EUPOS has been established by Head Office of Geodesy and Cartography in frame of EUPOS project. The reference stations network presently consists of 100 Polish and up to 21 foreign stations.

RTCM 3.x data from 109 stations is recorded in real-time using the BNC 2.5 software and stored in 30s interval using RINEX 2.11 format. Data from rest of the stations is downloaded via FTP servers in RINEX 2.11. Processing of hourly RINEX data is being done with half-hour delay by the batch Bernese GPS Software v.5.0 process, which is based on ambiguity fixed double-differenced solution of baselines.



GNSS vs METEO

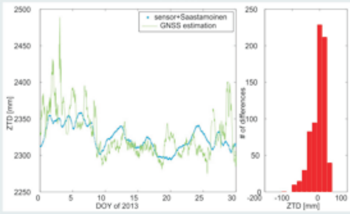


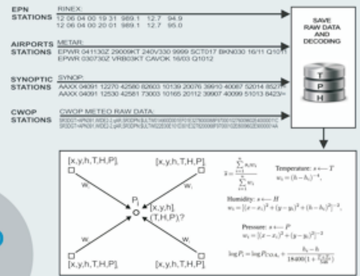
Figure shows example comparison of ZTDs from GNSS observations and ZTDs calculated from Saastamoinen formula using ground meteorological observations for station WROC (Wroclaw, Poland). It is visible that in this case ZTDs calculated using Saastamoinen formula and meteorological data do not compare well.

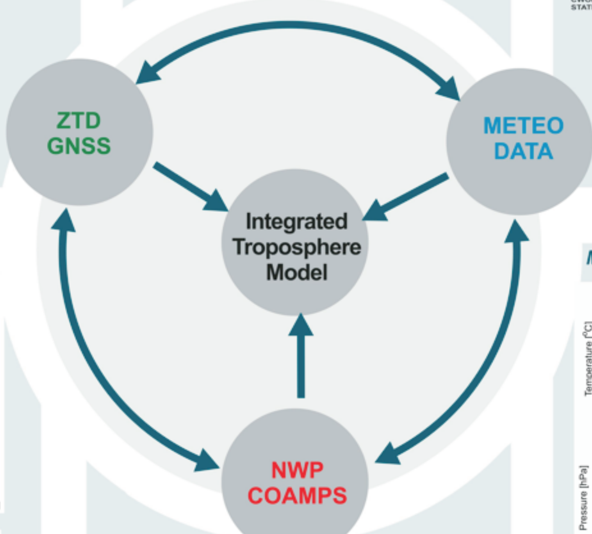
ZTD METEOROLOGICAL MODEL: IGGHZ-M

There are 15 EUREF Permanent Network (EPN) stations in Poland, equipped with new uniform meteorological infrastructure Paroscientific, Inc. MET4A or equivalent (BOR1). Meteorological data is supplied with airports (METAR) and synoptic (SYNOP) stations located in Poland.

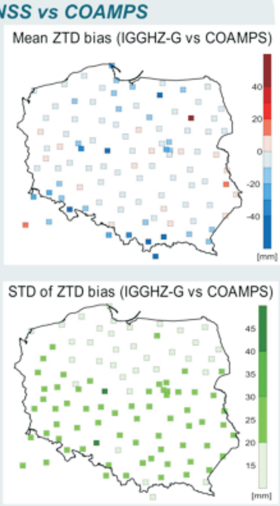
Three basic meteorological parameters are measured: pressure, temperature and relative humidity. The meteorological data are available with different time resolution, so the integration and cross-validation is required, as well as space interpolation procedure.

After interpolation of meteorological parameters into specific location, the ZTD value is obtained from Saastamoinens model.



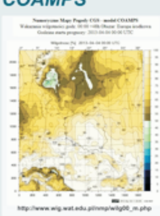


GNSS vs COAMPS



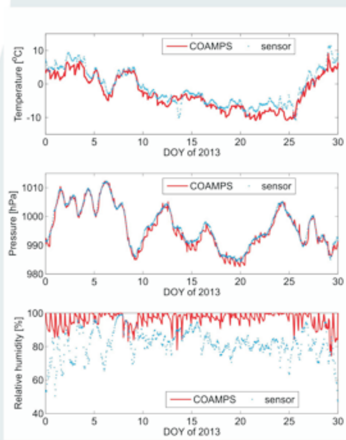
Figures show the ZTD (IGGHZ-G) bias and standard deviation for ASG-EUPOS network in Poland. These results were obtained from 1488 hourly sessions comparison with ZTD estimated from Saastamoinen (1972) formula, using meteorological data from NWP COAMPS model. Mean bias between analyzed ZTDs is -28.3 mm and standard deviation of biases is 22.5 mm.

COAMPS

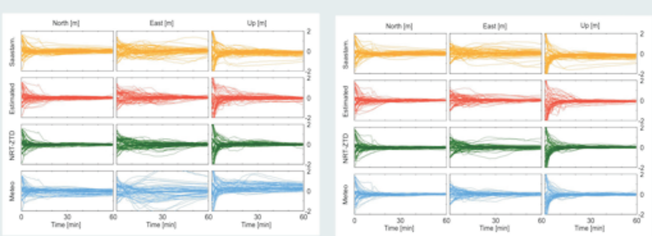


Mesoscale, nonhydrostatic coupled ocean and atmosphere model COAMPS (Coupled Ocean / Atmosphere Mesoscale Prediction System) was built and is being developed by the Research Laboratories of the U.S. Navy (Naval Reseach Laboratory). COAMPS relies on a number of important modules parameterization of physical phenomena: transport processes of radiation, cloud cover, precipitation, flows in a turbulent boundary layer flow moisture, vegetation, etc. Prognostic parameters are COAMPS model Exner function (the ratio of the pressure at a point in the atmosphere to the pressure on the surface of the earth), wind components (u, v, w), potential temperature, mixing ratios (steam, water, clouds, ice contained in the clouds, rain, snow, drizzle), the pressure on the earth's surface, the temperature and humidity of the Earth's land surface, the temperature of the ocean surface SST, aerosol concentrations, etc.

METEO vs COAMPS



Values of meteorological parameters obtained from meteorological sensors were compared with outputs from numerical weather prediction model COAMPS. Sample realization (for EPN station Wroclaw) is shown in figure 1. For majority of stations, values of temperature and air pressure acquired from both sources are very similar, which could lead to conclusion, that this two independent models can be used alternatively. However COAMPS overinterpolates relative humidity values.



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). Various scenarios of troposphere zenith delay were analysed. 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.

CONCLUSIONS

Institute of Geodesy and Geoinformatics (IGG) of Wroclaw University of Environmental and Life Sciences in Poland has developed high-resolution model of the state of the troposphere. This model integrates GNSS and meteorological data, as well as take advantage on numerical weather prediction models (COAMPS). The individual components are subjects of cross validation and peer review in the domain of meteorological parameters (temperature, pressure and relative humidity) and Zenith Troposphere Delay (ZTD). On the basis of this information, one can calculate the ZTD in real or near real-time for any place inside the model.

Application of determined troposphere delay into positioning increase accuracy and reliability both in autonomous and relative positioning. The tests showed, that tor real-time PPP the use of accurate information about ZTD reduces the initialization time. For a fully operational real-time service, it remains to develop a data transfer format to exchange troposphere data, since no such format exists yet.

This work has been supported by the Ministry of Science and Higher Education: research projects No N N526 197238 and N R09 0010 10, the Head Office of Geodesy and Cartography, the Wroclaw Center of Networking and Supercomputing (http://www.wcss.wroc.pl/): computational grant using Matlab Software License No: 101979 and realized in the frame of WG4.3.3 "Integration of GNSS atmosphere models with NWP models" of Sub-commission 4.3 "Remote Sensing and Modelling of the Atmosphere" of Commission 4 "Positioning & Applications" of International Association of Geodesy