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Preliminary results on performance of new ultra-fast static positioning module – POZGEO-2 in areas outside the ASG-EUPOS network

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Abstract: The presented preliminary research concerns the accuracy and reliability of new ultra-fast static positioning module – POZGEO-2 – in case of processing GPS data collected outside the ASG-EUPOS network. Such a case requires extrapolation of the network-derived atmospheric corrections which limits correction accuracy and, therefore, has adverse effect on the carrier phase ambiguity resolution. The presented processing tests are based on processing 5-minute long observing sessions and show that precise positioning can be supported up to 35 km from the ASG-EUPOS borders. This means that precise positioning with POZGEO-2 module can be assured for the most of the border areas of Poland.

Key words: GPS, ASG-EUPOS, ultra-fast static positioning

1. Introduction

In ultra-fast static GNSS (Global Navigation Satellite Systems) positioning successful ambiguity resolution greatly depends on the accuracy of the applied atmospheric – ionospheric and tropospheric – corrections. In case of an active GNSS reference network, such corrections are usually derived from the network and subsequently provided to the user. The accuracy of these corrections is a function of spatial and temporal variability of the ionosphere and the troposphere, the average distance between network stations, and also depends on the location of the user with respect to the reference network, i.e. the solution geometry (Rizos 2002, Vollath et al., 2002, Kashani et al., 2005, Grejner – Brzezińska et al., 2009). However, in some cases, such as positioning in areas near network borders, a favorable geometry cannot be accomplished.

In 2008 Polish Head Office of Geodesy and Cartography established a multifunctional active reference network system – ASG-EUPOS. This system is built according to European Position Determination (EUPOS) system standards and offers a variety of positioning services(Bosy et al., 2007; Oruba et al., 2008). In 2010 ASG+ project was launched aiming at the improvement of the existing services of ASG-EUPOS system. One of the tasks in this project is the development of automatic, web-based ultra-fast positioning module. This module will provide the users with a static position based on five minutes of GNSS data collected anywhere within the network (Figurski et al., 2011). ASG-EUPOS system shares its data with systems in several neighboring countries, therefore providing corrections and supporting positioning at Polish borders. However, in case of neighboring countries with no reference network stations or shore areas, there are regions where the corrections have to be extrapolated (Fig. 1).

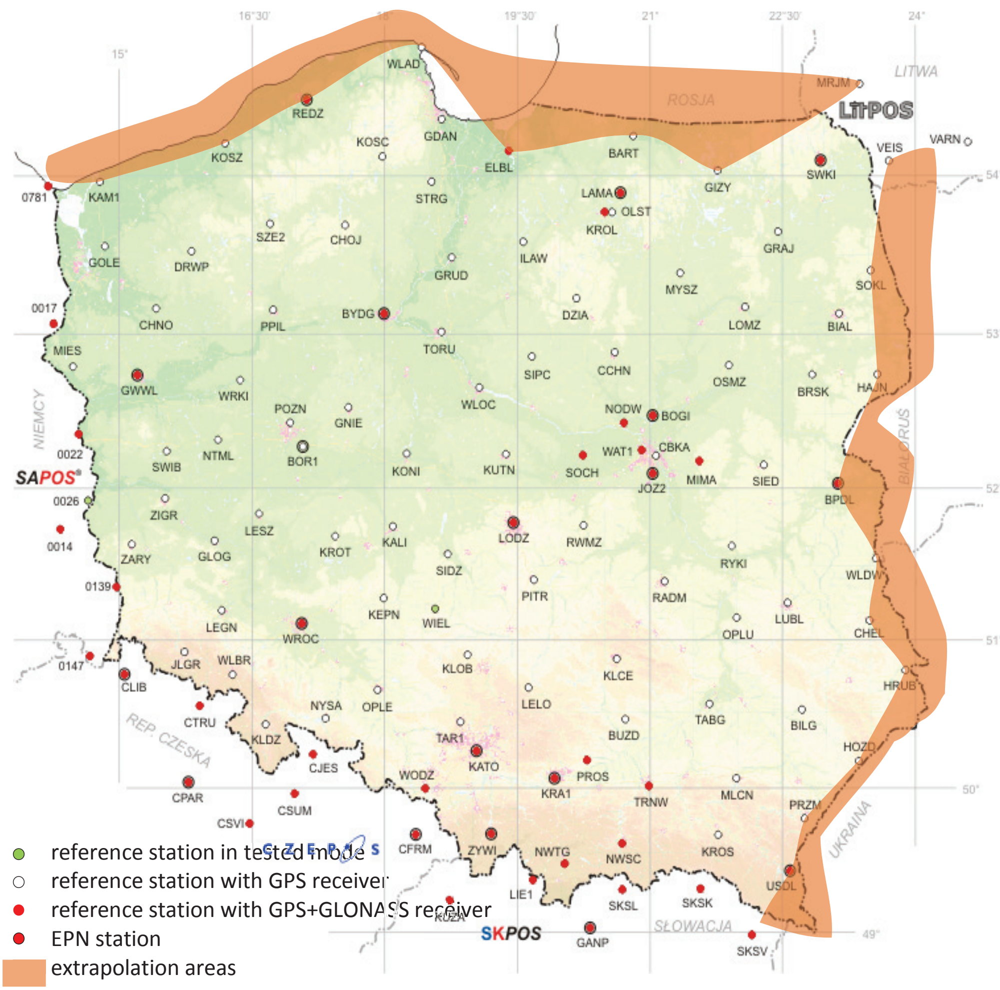

Fig. 1. ASG EUPOS system network and areas with correction extrapolation

The goal of this paper is to analyze the ultra-fast positioning accuracy and reliability in case of unfavorable solution geometry with the user located at different distances outside the reference station network. GPS data collected at several test locations were processed using the developed positioning module.

1.1. New POZGEO-2 module

ASG-EUPOS offers several real-time and post-processing services for variety of users. One of the posprocessing services is an automatic, on-line positioning module – POZGEO (Bosy et al., 2007; Oruba et al., 2008). Nowadays it allows processing RINEX data from sessions longer than 15 minutes and shorter than 24 hours, while 40-minute long sessions are preferred. Additionally, there are some restrictions on the number of epochs – RINEX files should include more than 720 epochs and less than 3600 epochs. Studies show that 40-minute long sessions provide good positioning accuracy, but on the other hand, this length of a session is not acceptable for many users for economic reasons. It is well known that the same accuracy can be obtained by ultra-fast positioning technique (Bakula, 2012; Cellmer, 2013; Wielgosz et al., 2011). Hence, in order to improve ASG-EUPOS services, POZGEO in particular, ASG+ project has started. A new module named POZGEO-2 is under development as one of the tasks within this project. The module methodology is based on the approach used in the GINPOS scientific GNSS post-processing software developed at the University of Warmia and Mazury in Olsztyn (Paziewski, 2012). POZGEO-2 requires minimum of 5 minutes of dual-frequency carrier phase and pseudorange GNSS data (with interval of 10 seconds). RINEX data files are sent by the users through a dedicated web page. Data processing is performed in relative geometry-based model. Position is obtained in a network (multi-station) solution using GNSS data from three surrounding ASG-EUPOS permanent stations. Model parameter estimation is based on sequential LSA (Least Squares Adjustment) with constraint equations. In the adjustment all mathematical correlations between the observations are taken into account. The LAMBDA method is applied for the ambiguity resolution (Teunissen, 1995). POZGEO-2 uses information about atmospheric delays from other modules, dedicated for atmosphere modelling, developed within the ASG+ project. The new module is capable of processing GPS and Galileo data (L1/E1, L2 and L5/E5a frequencies). It is expected that POZGEO-2 will offer horizontal accuracy of 2 cm (Figurski et al., 2011).

2. Experiment

Since the goal of this research is to test the accuracy of the POZGEO-2 service in case of the atmospheric correction extrapolation, a test sub-network including selected ASG-EUPOS stations was processed. In addition, several test sites were surveyed simulating geometry of the border areas. In the presented experiment dual-frequency pseudorange and carrier phase GPS data were used. An 8-hour session was divided into 5-minute sessions resulting in 96 independent sessions. ASG-EUPOS stations: ZARY, GLOG, LEGN served as reference stations and RR04, PP11, PP14, RR03, WROC were the test sites located at different distances from the reference network (Fig. 2). The experiments were carried out on 19 July 2012 since that day reflected regular ionospheric conditions when the Ap index amounted to 5.

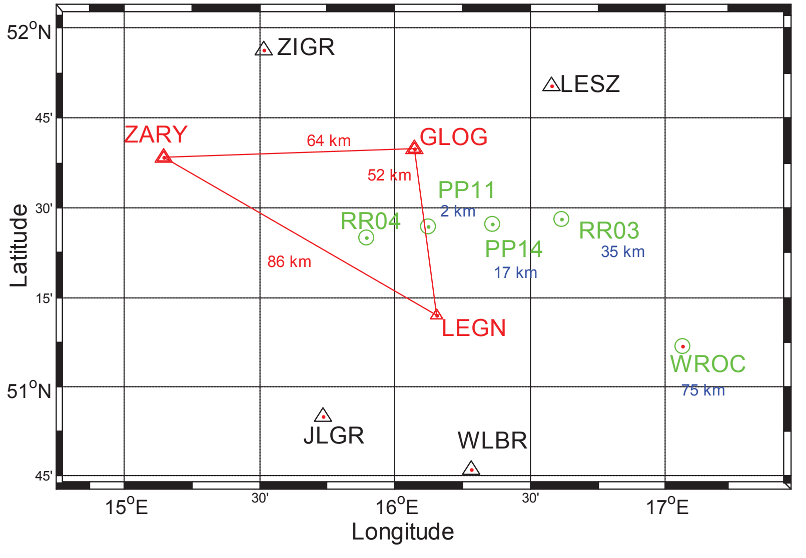

Fig. 2. Test network geometry (red – reference stations, green – test sites)

2.1. Processing scheme

The beta version of automatic POZGEO-2 post-processing module developed at University of Warmia and Mazury in Olsztyn (UWM) was used for data processing. The ionospheric refraction was mitigated using corrections derived by ASG+ ionosphere modeling module (Krypiak-Gregorczyk et al., 2013).The tropospheric refraction was mitigated using corrections derived by ASG+ troposphere modeling module (Hadas et al., 2013; Wielgosz et al., 2013). The corrections were extrapolated to the test site locations. A multi-station (network) solution was applied and W-ratio test with threshold of 2.5 (determined empirically) was used for the ambiguity selection validation. The resulting positions from independent processing of 5-minute sessions were compared to the reference positions obtained from processing of 8-hour session with Bernese 5.0 software (Dach et al., 2007).

2.2. Test geometry

Five different geometries (user locations) were analyzed (Fig. 3):
– RR04 surveyed point inside the test network,
– PP11 surveyed point almost on the network border,
– PP14 surveyed point 17 km away from the network border,
– RR03 surveyed point 35 km away from the network border,
– WROC surveyed point 75 km away from the network border.

2.3. Analyzed parameters

The analyzed resulting parameters were:
– coordinate residuals with respect to the reference position (dN, dE, dH) and their mean values (Fig. 3, Tab. 1),
– coordinate repeatability (standard deviations – std_N, std_E, std_H),
– ratio of sessions with correctly resolved and validated ambiguities (AVSR – Ambiguity Resolution and Validation Success Rate),
– ratio of sessions with ambiguity validation failure – when wrong ambiguities passed the validation test (AVFR – Ambiguity Validation Failure Rate).

3. Processing Results

Figure 3 shows coordinate residuals of the test sites that were obtained with different solution geometries. Coordinate residuals obtained with correctly resolved and validated ambiguities are marked with dots (horizontal – green dots, vertical – red dots). Coordinate residuals obtained with wrong ambiguities that passed the discrimination test and resulted in erroneous positions are marked with crosses (AVFR statistics). The results in the figure show that for the site located within the network (RR04) and for the sites close to the border (up to 35 kilometers) the extrapolated atmospheric corrections can support fast ambiguity resolution. This in turn results in accurate position with horizontal residuals under ±2 cm limit and vertical residuals under ±5 cm limit. On the other hand, in case of the site located 70 km outside the network (WROC) the results are poor. This is due to considerable errors in the interpolated atmospheric corrections that force wrong ambiguity solution. What is more, in some cases wrong ambiguities pass the validation test, resulting in biased positions.

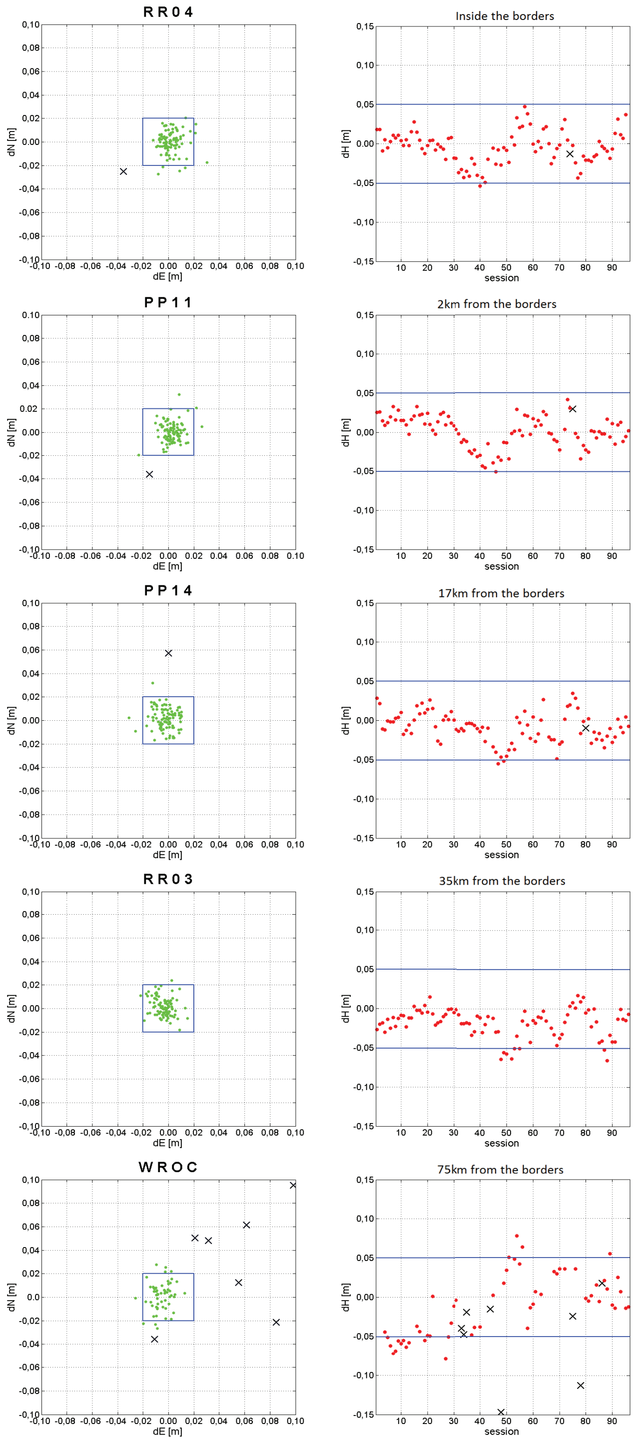

Fig. 3. Test sites' horizontal (left) and vertical (right) coordinate residuals obtained on 19 July 2012

Table 1 confirms the results presented in Figure 3. The percentage of sessions with correctly resolved and validated ambiguities (AVSR) is very high and amounts to 96.9% for the sites located both inside the reference network or near the network (up to 34 km). For each of these sites, the incorrect ambiguities passed the validation test only in case of a single session. In case of correctly solved ambiguities, the horizontal coordinate residuals are at similar level for each station and the impact of the distance from the network border is very limited. However, the height component residuals show clear dependence on the distance, most probably because of the decreasing accuracy of the extrapolated tropospheric corrections. This is due to the fact that the troposphere decorreclates with the distance and the correction extrapolation may not properly reflect actual tropospheric conditions at a location away from the reference network.

As it was expected much worse results were obtained for the WROC site (AVSR = 58,3%), which is located as far as 75 km from the network border. In this case, solutions with wrong ambiguities that were not detected (AVFR) reached as much as 17.7% – resulting in low reliability of the solutions. This initial study suggests that the surveyed points should not be located more than 35 km from the network borders. On the other hand, most of the border and shore areas in Poland are located closer than 35 km from the reference stations.

Table 1. Statistics of the coordinate residuals and ambiguity resolution performance for each test site

	distance	dN [m]	dE [m]	dU [m]	std N [m]	std E [m]	std U [m]	AVSR [%]	AVF [%]
RR 04	-	0.000	0.002	-0.005	0.010	0.008	0.021	96.9	1.0
PP 11	2 km	0.000	0.002	0.001	0.009	0.007	0.020	96.9	1.0
PP 14	17 km	0.002	-0.003	-0.009	0.011	0.008	0.019	96.9	1.0
RR 03	35 km	0.002	-0.004	-0.018	0.008	0.007	0.018	96.9	0.0
WROC	75 km	-0.025	0.003	0.030	0.128	0.052	0.197	58.3	17.7

4. Summary

The present research shows the positioning performance of POZGEO-2 module in areas outside the reference network with no data from the neighboring countries. In such case the extrapolation of the network-derived atmospheric correction is required. The obtained results suggest that the precise and reliable position in the ultra-fast static mode can be supported up to 35 km from the ASG-EUPOS network borders. This covers most of the territory within the borders of Poland. It should be noted that processing of 5-minute long observing sessions allows for 2 cm horizontal and 5 cm vertical position accuracy.

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Wstępne badania dokładności nowego modułu ultra-szybkiego pozycjonowania – POZGEO-2 – na obszarach znajdujących się poza granicami sieci ASG-EUPOS

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Streszczenie

W pracy prezentowane są badania dotyczące dokładności i wiarygodności pozycji wyznaczanej z wykorzystaniem nowego modułu ultra-szybkiego pozycjonowania – POZGEO-2 opracowanego dla systemu ASG-EUPOS. Przedstawione testy obliczeniowe dotyczą szczególnego przypadku wyznaczania pozycji, gdy użytkownik znajduje się poza granicami sieci stacji referencyjnych. W takich warunkach wymagana jest ekstrapolacja sieciowych poprawek atmosferycznych. Wpływa to negatywnie na dokładność tych poprawek i może doprowadzić do sytuacji, w której wyznaczenie nieoznaczoności będzie niemożliwe. Prezentowane badania oparte są na pięciominutowych sesjach obserwacyjnych i pokazują, że poprawki mogą być ekstrapolowane dla obszarów położonych do około 35 km od granic sieci ASG-EUPOS. Oznacza to, że w praktyce precyzyjne pozycjonowanie ultra-szybkie z użyciem modułu POZGEO-2 może być zapewnione dla niemal całego obszaru Polski.