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Analysis of Coordinates Time Series Obtained Using the NAWGEO Service of the ASG-EUPOS System**

1. Introduction

Since June 2008, when the ASG-EUPOS network of permanent stations was started in Poland, many geodesists take advantage of the capabilities that are given by using the station network during geodesic measurements. One of the most often used measuring techniques based on the ASG-EUPOS network is the RTK GPS real-time measurement [1, 3]. Apart from formal and legal aspects of conducting such geodesic work, an important factor is the obtained accuracy of geodesic measurements in the RTK GPS mode using the ASG-EUPOS network. Before the start-up of the system and after its implementation, studies are constantly being conducted on the operation of permanent station networks and their influence on the achieved accuracy of geodesic field measurements [4, 5]. The authors of this article have conducted an analysis of the accuracy of determining positions using RTK GPS technology, depending on the type of corrections used and the number of base stations used during the measurement. For this purpose, an antenna receiving GPS satellite signals operating in RTK mode for nearly 2 months was installed on the roof of the C-4 building of the Faculty of Mining Surveying and Environmental Engineering at AGH in Cracow. Test measurements were conducted from July 7th to September 7th, 2009.

The distance of the mobile receiver from the reference station has the main influence on the final accuracy of coordinates obtained during measurement. The method of calculating so-called observational corrections – based on observations from a single base station or from the station network – also has an effect. For the purpose of minimizing the error resulting from the distance between GPS receivers, surface corrections obtained by means of the appropriate software are used

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for measurements (RTK network corrections). The NAWGEO service of the ASG-EUPOS system was used to generate RTK surface corrections in the described tests. Comparative analysis of the determined position was conducted based on the network/surface corrections available in VRS (Virtual Reference Station), MAC (Master and Auxiliary Concept) and FKP (*Flächenkorrekeurparameter*) formats. Corrections obtained from the KRAW, PROS, and KATO permanent stations (individually) were also used for measuring tests in RTK mode. Coordinates obtained from network solutions as well as those calculated in reference to the individual permanent stations listed above were subjected to the evaluation of the accuracy of determination of the position of AGH0.

2. Measuring Experiment

From July 7th to September 7th 2009, continuous determination of point coordinates using GPS satellite technology in RTK mode was conducted on the roof of the C-4 building of the Faculty of Mining Surveying and Environmental Engineering. A Trimble SPS851 type receiver and a Zephyr Geodetic 2 antenna, mounted at the AGH0 measuring point (Fig. 1), were used for measurement [2]. Measurements were taken using various types of corrections that were given access to by the ASG-EUPOS system in the NAWGEO service. The AGH0 measuring point in which measurements were taken, is located at a distance of 17.5 m from the KRAW permanent station used in test measurements as a base station. The locations of the nearest permanent stations belonging to the ASG-EUPOS system have been presented in figure 2.

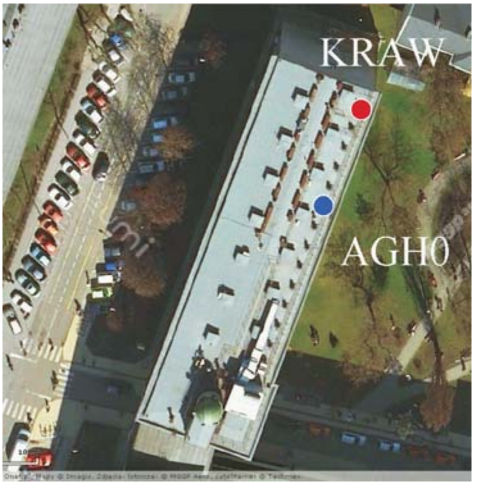

Fig. 1. Location of the KRAW permanent station and the AGH0 control point

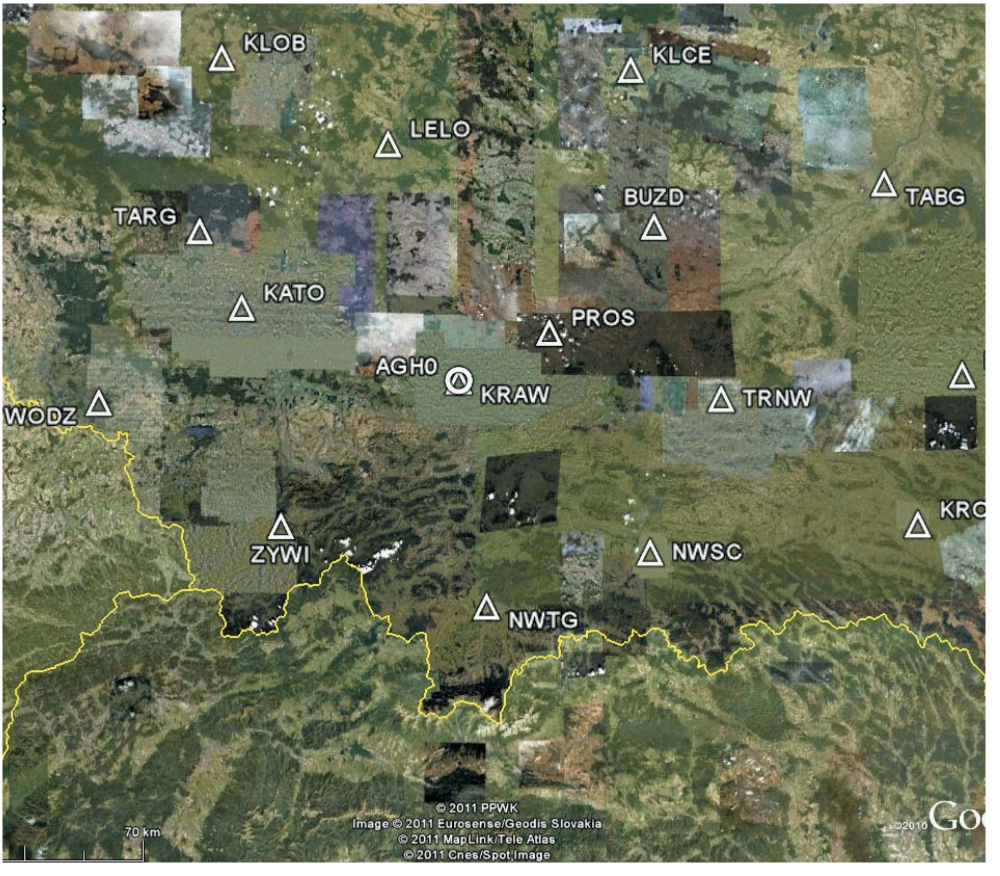

Fig. 2. Locations of ASG-EUPOS system permanent stations near the AGH0 test point

The result of the conducted measurement were coordinate time series obtained using individual types of observational corrections from the individual base stations: KRAW, KATO, PROS, as well as from network solutions: VRS, MAC, and FKP. For each type of correction, time series with a length of a minimum of 48 hours with measuring intervals of one second were registered.

Figures 3–7 present the results of determinations of horizontal x and y coordinates in the local system with the origin at the AGH0 testing point and ellipsoidal heights h. The horizontal axis of all charts includes an interval of 24 hours, and the values of presented coordinates are expressed in centimeters.

Figure 3 presents the results of determinations of coordinates of the AGH0 testing point in reference to the individual KRAW station. The KRAW station is distant by 17.5 m from the determined point, which is why this measurement can be treated as a control measurement taken in optimal conditions. As results from the presented graphs, repeatability of determination of coordinates during the entire measuring period for horizontal coordinates does not exceed 3 cm for the northern component (x) and 2 cm for the eastern component (y). The ellipsoidal height is determined with a repeatability that is not worse than 5 cm. Due to the fact that a typical RTK mode measurement is based on the registration of only several measuring epochs, the accuracy criterion for determining coordinates with this method was accepted to be the maximum differences in coordinates obtained during a measurement taken over a long period of time. A testing measurement period of 24 hours ensures consideration of all possible satellite configurations at a given measuring station, and thus, makes it possible to study the effect of this configuration on the determination of coordinates.

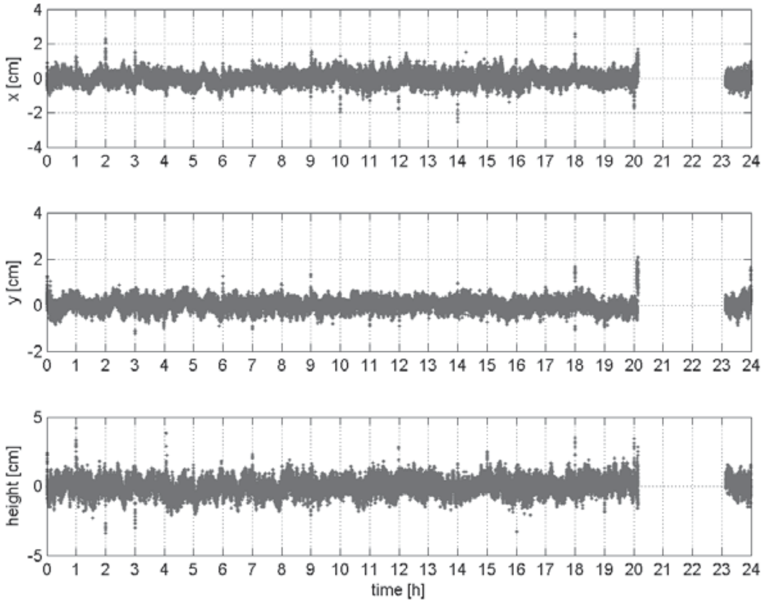

Fig. 3. Time series of x, y, h coordinates determined in reference to the KRAW station, at a distance of 17.5 m from the AGH0 testing point

The graphs shown in figures 4 and 5 present the coordinate time serirs obtained in reference to the PROS station in Proszowice, distant by about 30 km from the testing point, and in reference to the KATO station in Katowice, distant by about 67 km. In these cases, the repeatability of horizontal coordinate determinations reaches values of a dozen centimeters, and for ellipsoidal height, above 20 cm. Data gaps in the coordinate time series in case of measurements to the PROS and KATO stations individually, was caused by repeated problems with server connectivity of ASG-EUPOS system corrections during the realization of the experiment.

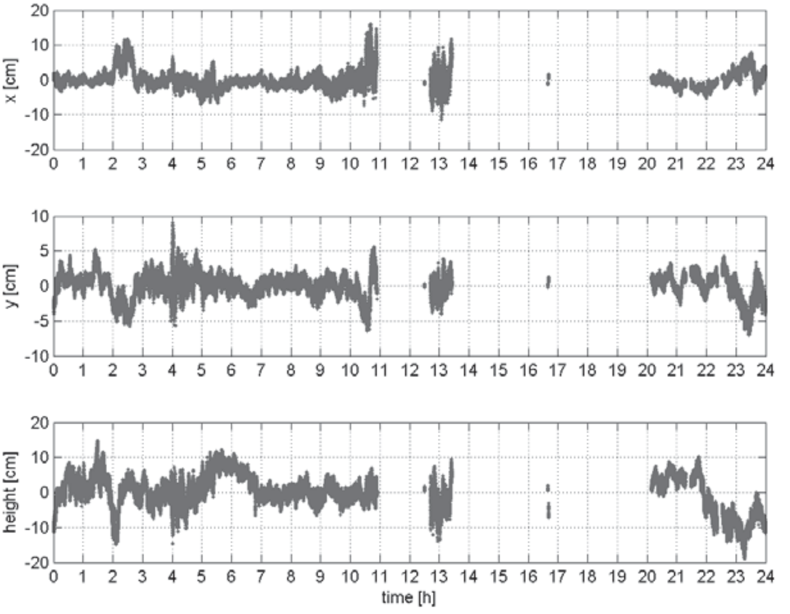

Fig. 4. Time series of *x*, *y*, *h* coordinates determined in reference to the PROS station, at a distance of about 30 km from the AGH0 testing point

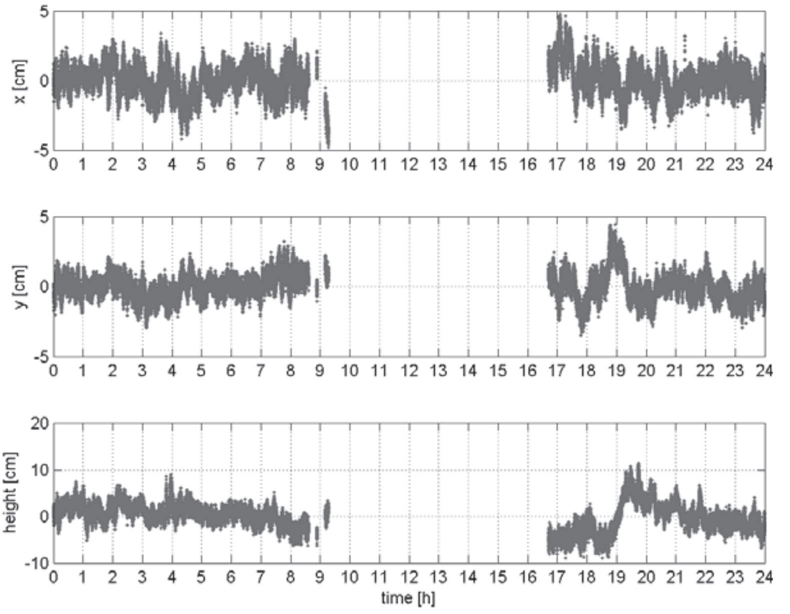

Fig. 5. Time series of *x*, *y*, *h* coordinates determined in reference to the KATO station, at a distance of about 67 km from the AGH0 testing point

The repeatability of coordinate determination using network corrections is practically the same as in the case of reference to the nearby KRAW individual station. Figure 6 presents coordinates obtained from a 24 hour measurement using VRS corrections of the NAWGEO service. Similarly as in the case of the very close base station, repeatability of horizontal coordinates does not exceed 2–3 cm, and for ellipsoidal height 5 cm. Similar results were also obtained for the other types of corrections: MAC and KFP. These quantities should be considered as the best possible to be obtained based on GPS satellite measurements in RTK mode.

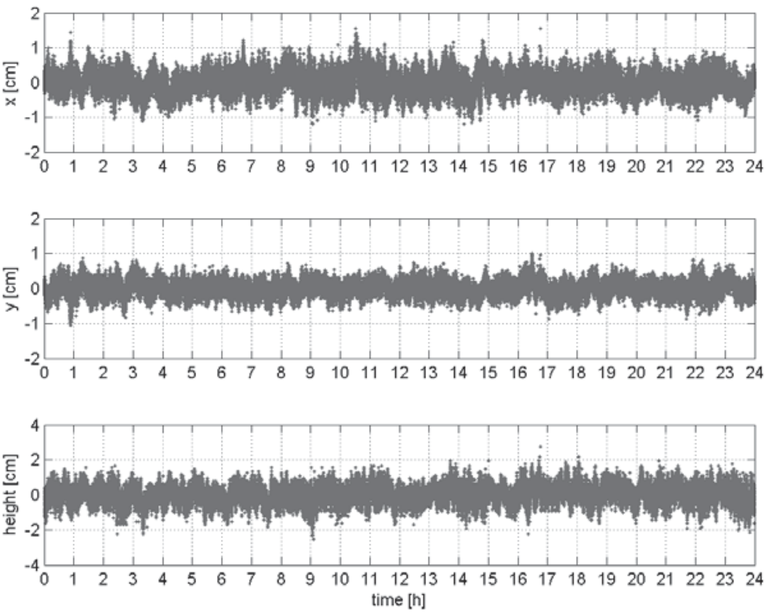

Fig. 6. Time series of *x*, *y*, *h* coordinates determined from the VRS network solution

On the day of 16.08.2009, during the conducting of test measurements in VRS mode, a break in the operation of the KRAW station occurred, which was immediately reflected in the accuracy of the determined position (Fig. 7). Despite the receiver not interrupting operation in RTK mode – it still received data from the NAWGEO service – the quality of coordinate determination decreased significantly. After excluding the closest station from the network experiment, determination repeatability decreased to 8–10 cm horizontally and to more than a 10 cm in ellipsoidal height. After restart of the KRAW station, the situation returned to the state as before the break (Fig. 8).

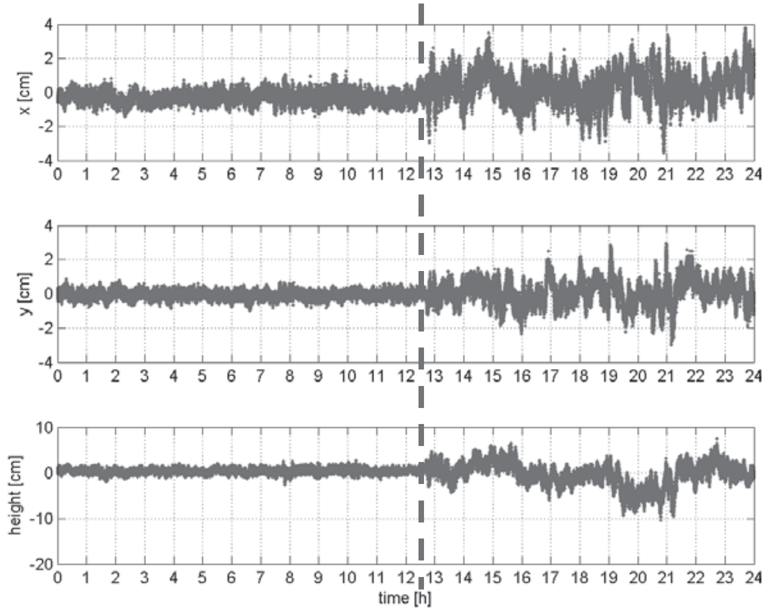

Fig. 7. Time series of x, y, h coordinates determined from the VRS network solution with the KRAW station inactive (the moment of deactivation of the KRAW permanent station has been marked with a broken line)

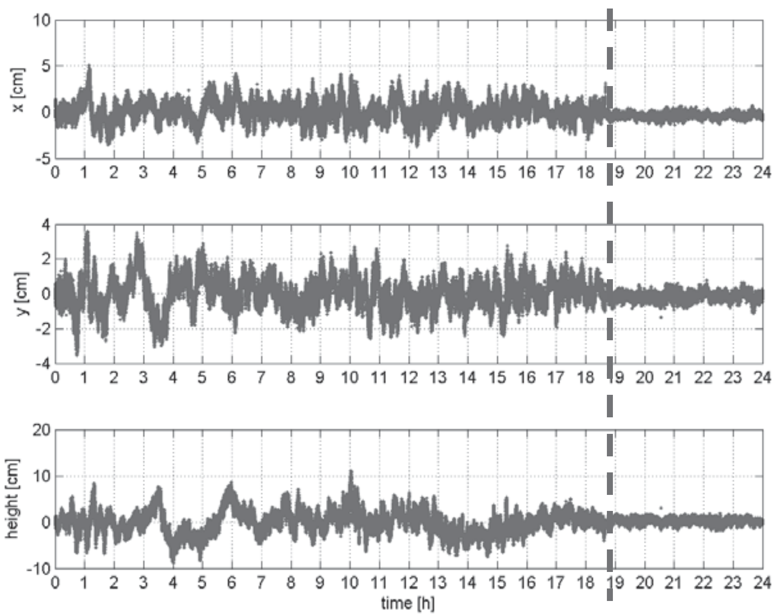

Fig. 8. Time series of x, y, h coordinates determined from the VRS network solution with the KRAW station inactive (the moment of reactivation of the KRAW permanent station has been marked with a broken line)

3. Conclusions

Based on the conducted test measurements, the capabilities for obtaining reliable and repeatable coordinate determinations using the RTK GPS method were specified. In the case of small distances of base stations to the determined point – results similar to the case of the surface correction were achieved in the single station mode at optimal measuring conditions (uncovered horizon, no satellite signal disturbances): repeatability Δx, Δy = 2–3 cm, Δh = 5 cm. At greater distances of the order of more than a dozen kilometers from the base station, repeatability of determining horizontal coordinates can drop to about 10 cm, and for height, to 20 cm or more. Determination of point coordinates using the RTK network technique, in the case of significant distance (more than a dozen kilometers) from the closest base station, decidedly deviates in accuracy from determinations made in optimal conditions.

References

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[2] Trimble® SPSx51 Modular GPS Receivers User Guide, Trimble, Version 3.70, Revision A, August 2008.

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