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ACCURACY OF DETERMINING HEIGHT DIFFERENCES BASED ON NRTK VRS MEASUREMENTS AND USING QUASI-GEOID MODEL

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Summary

The paper analyses the accuracy of the determination of normal heights in the national spatial reference system using the PL-geoid-2011 quasi-geoid model. The heights were determined using the PL-EVRF2007-NH normal height system. The paper discusses the results of a measurement experiment consisting in measuring 8 points with the use of the Network Real Time Kinematic (NRTK) technique and the Virtual Reference Station (VRS) surface correction generated on the basis of the TPI NETpro commercial network of reference stations and with the use of two global satellite systems (GPS, GLONASS). In the experiment, three measurement schemes were evaluated in relation to the number of measurement epochs recorded above the designated point, as well as the order of recording points. The conducted measurement experiment allowed to determine which of the proposed schemes guarantees the best accuracy from the point of view of establishing a height measurement network with the use of the NRTK technique and VRS corrections. The tests showed that it is possible to determine the height difference between points using the NRTK technique and the VRS method with an accuracy of 0.01m. However, to ensure adequate accuracy, elevation differences must be defined as the differences of the measured heights and should be determined several times and based on independent measurements at the beginning and end of the levelling section. Thus, determining elevation differences with the use of the NRTK VRS technique may be particularly effective in areas with large differences in height, where the determination of elevation differences with the use of classical methods is time-consuming. The obtained elevation differences require tying to the points of the height control network with the use of classical methods.

Keywords

VRS • NRTK • PL-geoid-2011 • height • quasi-geoid

1. Introduction

Height measurements are one of the main tasks of land surveying, and in many cases they require high accuracy. The classical methods of geometric levelling and trigonometric levelling are predominant among the methods used to determine elevation differences. Currently, height determination based on Global Navigation Satellite

Systems (GNSS) satellite measurements is also becoming increasingly popular, used together with both static technology and kinematic methods, i.e. Real Time Kinematic (RTK) and Network Real Time Kinematic (NRTK). However, it should be emphasised that despite the significant increase in the use of satellite techniques in everyday geodetic work, there are still some tasks that require such accuracy of height determination, which at the moment is impossible to achieve through GNSS measurements.

As is well known, elevation differences and heights determined on the basis of geometric or trigonometric levelling are not the same ellipsoidal heights that are determined by GNSS measurements [Meyer et al. 2006]. The procedure for determining orthometric or normal heights on the basis of ellipsoidal heights needs to take into account the information on the gravitational field, which in turn can be provided in the form of geoid models operative in a given area, to determine orthometric heights, or quasi-geoid models, to determine normal heights.

The height system that is currently operating in Poland is the PL-EVRF2007-NH normal height system. The quasi-geoid model in force since April 2022 is the PL-geoid2021 model [Technical Report 2021], which replaced the former PL-geoid-2011 model [Kadaj 2014]. Both the PL-geoid-2011 and PL-geoid2021 models are used to convert ellipsoidal heights from the PL-ETRF2000-GRS80h system to normal heights in the PL-EVRF2007-NH system, which covers the territory of Poland. The PL-geoid-2011 model was developed on the basis of the global geopotential EGM2008 model, which was transformed by the interpolation method into a control network consisting of satellite-levelling points [Kadaj 2014]. The PL-geoid2021 model was developed as a model of the quasi-geoid obtained through the transformation of the gravimetric quasi-geoid model to the network of the satellite-levelling points [Technical Report 2021]. The differences between the PL-geoid2021 and PL-geoid-2011 models are in Poland ± 3 cm on average [Technical Report 2021]. As previous research shows, the key issue in determining normal heights is the selection of an appropriate quasi-geoid model [Krzan et al. 2017, Stępniak et al. 2017].

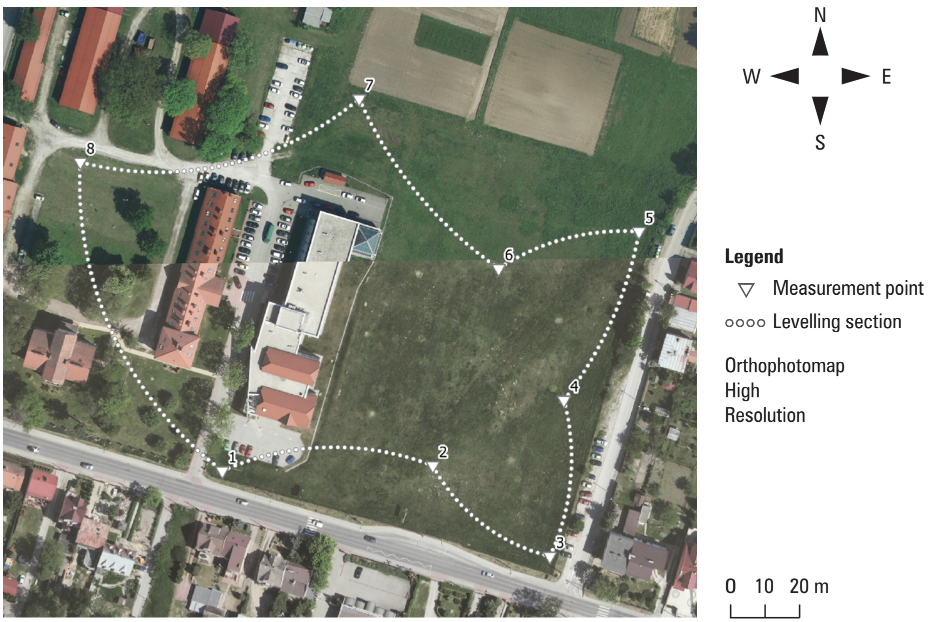
In the case of height determination with GNSS measurements, in addition to adopting an appropriate quasi-geoid or geoid model for determining height in the current height system, the selection of the appropriate measurement technique also plays an important role. In the case of RTK measurements, the distance of the rover from the reference station is significant, as it has direct influence on errors occurrence, such as atmospheric errors. According to Grejner-Brzezinska et al. [2005], the order of the accuracy of the height component determination is 0.20 m, when a distance of the rover from the reference station is 100–300 km (assuming that atmospheric corrections are not considered). At the same time, when the distance from the base station is reduced to 30–40 km, the height component determination is accurate to the level of centimetres [Grejner-Brzezinska et al. 2005]. Thus, higher accuracy of the determination of the vertical component should be expected when NRTK measurements are used. Dawidowicz [2013a] assessed the accuracy of the heights determined on the basis of NRTK measurements in relation to the heights obtained with precision levelling, achieving an accuracy of 0.018 m for height. Nevertheless, studies conducted by Gumus et al. [2016] have shown that RTK measurements give better results when it comes to determining height than NRTK measurements. In the case of NRTK measurements, an accuracy of 0.04 m can be achieved for the height component, even in border regions [Garrido et al. 2012]. At the same time, Gumus et al. [2016] verified the influence of individual surface corrections on the height determination in NRTK measurements, showing that the best results in this instance were obtained for VRS (Virtual Reference Station) corrections. While a study by Garrido et al. [2011] showed that the accuracy of the height component determination in NRTK measurements using VRS and Master Auxiliary Concept (MAC) corrections has an accuracy of 0.05 m. Then, Bae et al. [2015] also took into account the influence of the length of NRTK measurements at the point on the accuracy of the ellipsoidal heights determination. These studies [Bae et al. 2015] did not show significant changes in the obtained mean values of ellipsoidal height errors, while indicating that the variance of solutions is inversely proportional to the duration of the measurement due to the smoothing effect. As to static measurements and limiting to only Global Positionig System (GPS) technology, discrepancies of 0.03m were recorded between height differences in static measurements and traditional levelling [Elaksher et al. 2016]. Firuzabadì and King [2012] reported an accuracy of 0.01 m of height determination in static measurements lasting 3 hours or more and for distances of less than 200 km from the base station, or for the use of 4 or more base stations and 2-hour sessions. As Berber et al. [2012] point out, shortening the observation period is more important for determining the vertical components than for the horizontal components, and conclude that only with longer observation periods it is possible to reduce the error of height determination to 0.02 m. Meanwhile, a study by Elaksher et al. [2020] indicate that static measurements lasting 2 hours can provide about 0.03 m discrepancy in height differences when about 20 GNSS satellites are tracked. At the same time, they point out that these discrepancies could reach 0.05 m when the measurement period is reduced to 20 minutes and the number of tracked satellites is reduced to 15.

The aim of this study is to determine the variability of normal height difference values obtained using a dual-frequency satellite receiver equipped with a selected quasi-geoid model, i.e. PL-geoid-2011, and using the NRTK technique and the VRS correction based on the TPI NETpro commercial station network. The measurement experiment carried out for this purpose contributes also to the research on whether the randomness of errors occurring during height measurement and the accuracy of the technique used and the measurement scheme adopted decrease during the determination of the elevation as a difference of the determined heights and thus allow the elevation differences itself to be determined with a high degree of precision.

2. Materials and methods

Research area

This research includes the measurement of 8 points. The points were located in the eastern part of the city of Kraków (TERYT 126102_9), cadastral district 0048, within the Campus of the Faculty of Environmental Engineering and Land Surveying. They are a part of a control network that is used for educational purposes, which is a type of geodetic control network with points permanently stabilised in the ground. The measurement was performed using the VRS surface correction and the NRTK technique based on the NETpro TPI station network and two satellite systems (GPS+GLONASS). Points of TPI NETpro are a lower order geodetic control network, with a horizontal position error of no more than 0.07m relative to the reference points and an elevation error of less than 0.01m. Detailed characteristics of the geometry of the network used on Poland's territory are included in Kudas and Wnęk [2021]. The NETpro TPI network densifies the ASG-EUPOS national reference station network, and its geometry is characterised, for example, in Kudas [2020]. The mutual configuration of the measurement points is shown in the Figure 1. Horizontal distances between neighbouring points are 79.7 m for levelling section 1–2, 56.0 m for section 2–3, 59.2 m for section 3–4, 79.7 m for section 4–5, 54.9 m for section 5–6, 83.0 m for leveling section 6–7, 108.1 m for section 7–8, 128.3 m for section 8–1. Whereas, the length of the entire levelling traverse formed by the measurement points is 648.8 m.



Source: Author's own study, based on the orthophotomap provided by https://mapy.geoportal.gov.pl

Fig. 1. Measurement points location

The measurement experiment consisted in collecting 15 positions of each point using the NRTK technique and the VRS method. The height coordinate was recorded in the PL-EVRF2007-NH system. The PL-GEOID-2011 model was used to convert the determined ellipsoidal heights from the PL-ETRF2000-GRS80h system to the

PL-EVRF2007-NH normal height system. The change in the distance between the height of the PL-geoid-2011 model and the surface of the GRS80 ellipsoid is shown in Figure 2. In the research area, this interval is approx. 39.83±0.01 m. The differences in height in the research area between the adopted PL-geoid-2011 quasi-geoid model and the PL-geoid-2021 model range from 0.0013 to 0.0019 m.

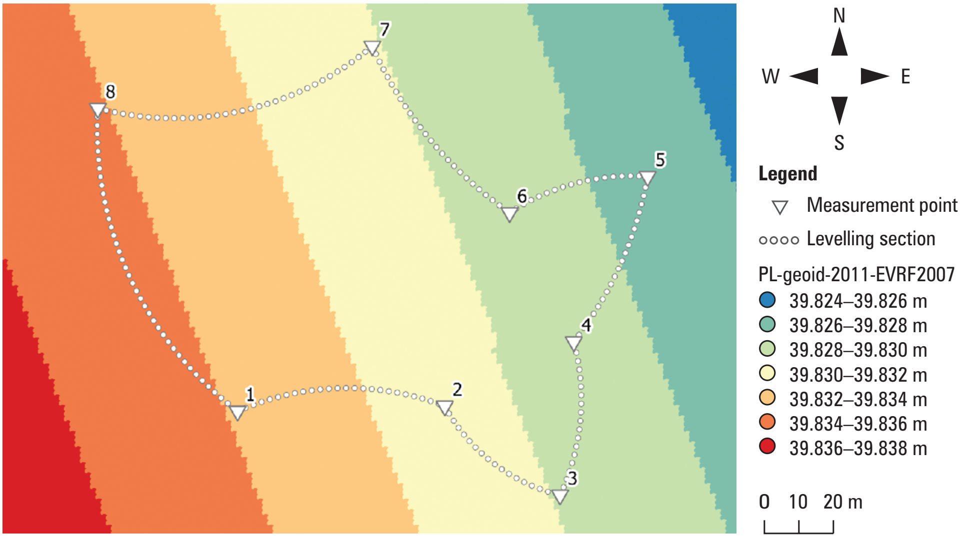


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Fig 2. Change in the spacing of the quasi-geoid PL-geoid-2011-EVRF2007 model from the surface of the GRS80 ellipsoid in the research area

Assumptions for the measurement experiment

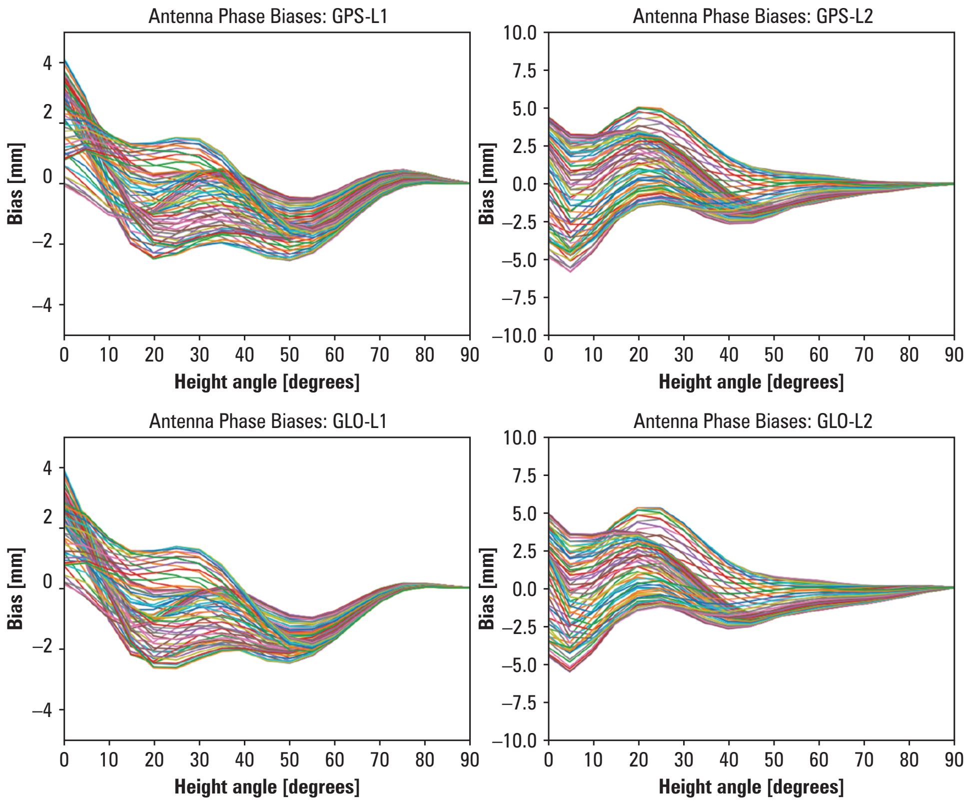
The following assumptions were made in the experiment:

- the determination of positions is based on the same stream of corrections,
- the same integrated receiver model is used,
- the receivers are equipped with the same quasi-geoid model,
- the cut-off mask of the horizon of the rover is 10°,
- position determination is carried out at the Position Dilution of Precision (PDOP) value < 6,
- each receiver determines the positions based on a different measurement variant.

Three measurement variants were used:

- *variant V1* – determination of the vertical position based on the registration of 15 measurement epochs at a given point, recording and re-determining after approx. 2 minutes the next position of the same point based on 15 measurement epochs;

- *variant V2* – determination of the vertical position based on the registration of 30 measurement epochs at a given point, recording and re-determining after approx. 2 minutes the next position of the same point based on 30 measurement epochs;
- *variant V3* – determination of the vertical position based on the registration of 30 measurement epochs at a given point, recording and moving to the next measurement point, performing the position determination at the next point based on the registration of 30 measurement epochs, returning to the starting point after measuring all points.



Source: https://trimbletools.com/Antenna_Info/IGS14/

Fig. 3. Antenna phase biases for GPS and Glonass L1 and L2 frequency

It should be noted that in the V3, there was a longer interval between consecutive measurements of the coordinates of the same point than was the case in the V1 and the V2.

The normal heights obtained in the measurement were used to determine elevation differences between the measured points, creating 8 levelling sections (Fig. 1) between permanently stabilised points. Elevation differences can be determined by creating different types of combinations of height differences between the start and end points.

The measurement was taken by the Trimble R8-3 integrated receivers, mounted on a 2-meter pole. According to the manufacturer's declaration, these receivers in the RTK mode and with a base vector up to 30 km have a vertical position accuracy of 15 mm + 1 ppm RMS, and in the case of a network solution (NRTK) by a vertical accuracy of 15 mm + 0.5 ppm RMS [Trimble R8-3 specification]. As noted by Perski et al. [2013] the antenna phase centre point, where satellite signals are received, usually does not coincide with the geometrical centre of the antenna and therefore a user intending to determine the position very accurately must include a corresponding shift in the measurements. In turn, as Dawidowicz [2013b] notes, the models of antenna calibration have a significant impact on errors in determining the height component. Due to the fact that individual units of the same antenna model differ from each other, measurements requiring the highest precision must use antennas with individual calibration. The characteristics of the errors of the antenna model used according to the data from the antex IGS14 file are presented in the Figure 3. Errors for the L1 frequency of GPS and GLONASS signals for satellites observed over 10° above the horizon take a value from –2.5 to 2 mm, and for the L2 frequency from approx. –5 to 5 mm.

Types of determined elevation differences

Dependent elevation differences

A possible number of position pairs without repetitions was determined between the recorded positions. Each of the tested elevation differences between measurement points can be determined 225 times in each of the measurement variants. This way of determining elevation differences makes the subsequent elevation differences dependent observations, because the set of elevation differences at the end point of a given levelling section is also the set of elevation differences of the start point of the next levelling section. The purpose of such a method of determining elevation differences is mainly to show the possible variability of the elevation differences that can be achieved by determining the difference in height obtained from the NRTK measurement.

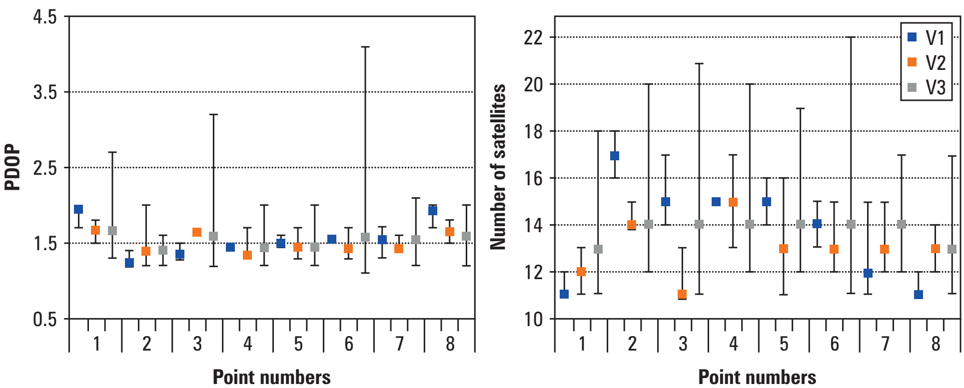
Independent elevation differences

With 15 recorded positions of each point, each elevation was also determined based on 7 pairs of height coordinates of these points, creating independent elevation differences. In this case, the last 7 records of each of the start points of the levelling section and the first 7 determinations of the next of the end points of the levelling section were used. Using the elevation differences defined as independent, it is possible to analyse whether the sum of the elevations of the levelling sections determined in this way is equal to 0 m, due to the fact that the points form a closed levelling traverse.

For each levelling section, the root mean square error (RMSE) value was determined, taking as the reference elevation differences value derived from the measurement using precise geometric levelling by the middle method taking into account the levelling normal correction. The levelling measurement was carried out using the Leica LS10 precision leveller. Due to the fact that the accuracy of measurements using the NRTK technique based on the NETpro TPI network in accordance with the legal regulations is determined at ±0.05 m for height, the calculations were carried out with an accuracy of 0.001 m, and the final results were given with an accuracy of 0.01 m.

3. Results and discussion

The area where the measurement experiment was carried out is not characterised by significant delevelling, and there were elevation differences in the range of approx. 0.1 to 2.7 m between the analysed measurement points. Therefore, also the height anomalies of the used quasi-geoid model PL-geoid-2011 do not change their values abruptly (Fig. 2). The measured sets of heights of the analysed points have different parameters of variation of the height value. Bearing in mind that the accuracy of height measurement, and consequently the determined elevation differences, was influenced by satellite observation conditions, the number of observed GPS+GLONASS satellites depending on the position of the measurement point and the value of the PDOP coefficient were discussed. The profile of these parameters along with extreme values depending on the measurement variant are presented in Figure 4. It should be noted that the PDOP parameter in most cases assumed the value of approx. 1.5, whereas extreme values were achieved only during the measurement taken at point 6, where in one case of the V3 variant the PDOP value equal to 4.2 was recorded. Between 11 and 22 satellites of the GPS and GLONASS constellations were observed during the measurement, with the smallest number of satellites observed at points 1, 3, 7 and 8. However, the decrease in the observed number of satellites did not affect the low values of the PDOP parameter during the measurement of these points.



Source: Authors' own study

Fig. 4. The profile of PDOP values and the number of tracked satellites depending on the measurement point and the measurement variant

The profile of the collected height sets depending on the measurement variant are presented in Figure 5. The sets are characterised by average, maximum and minimum

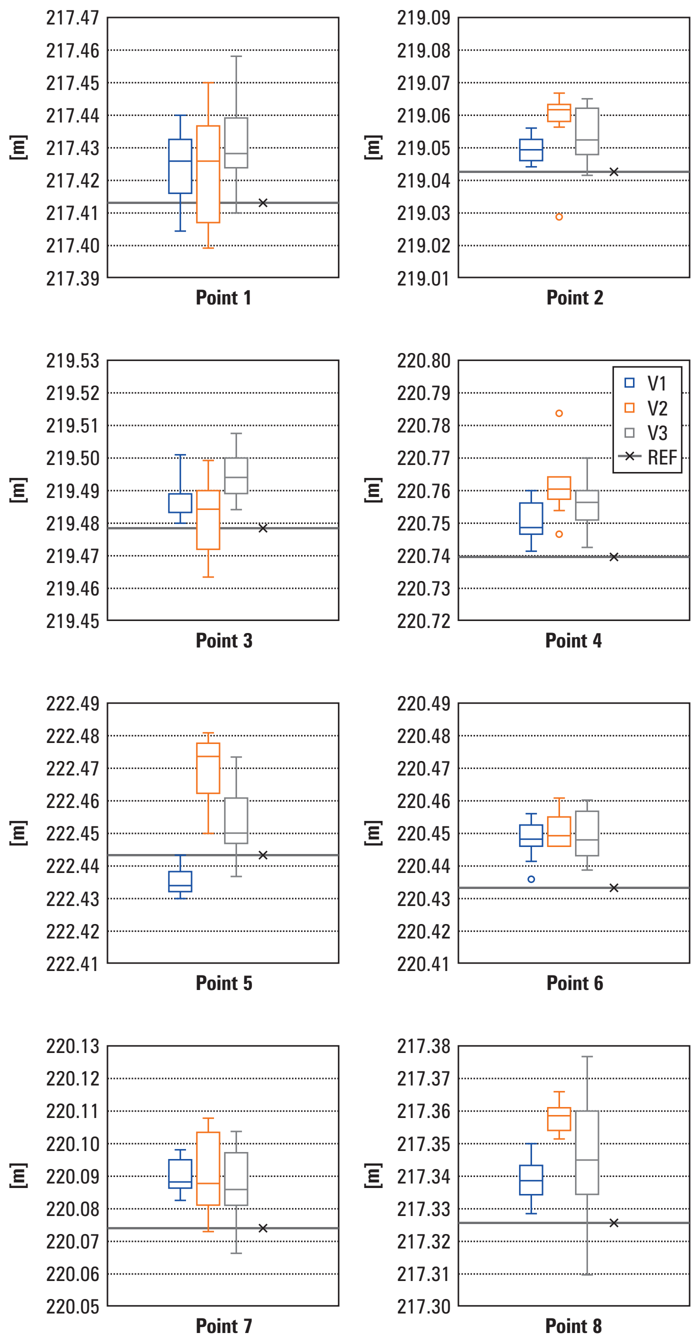


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Fig. 5. The profile of the measured heights depending on the variant and the measurement point

values, as well as outliers and in relation to the value of the reference height obtained from the measurement by precise geometric levelling in connection to the point of the national detailed height control network.

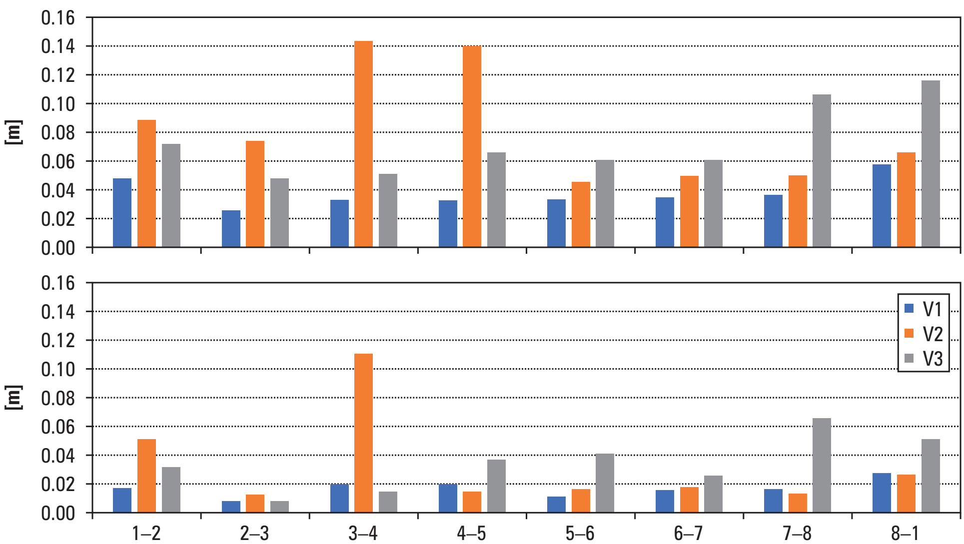
The smallest values of standard deviation of the sample from the average value (σ_H) were collected for the sets of points obtained for variant V1. The deviation reached values from 0.003 m (point 2) to 0.010 m (point 1), and on average was 0.006 m. The largest values σ_H have those height sets that were created in the V2 variant. In the case of V2, the standard deviation from the average value was between 0.004 m (point 8) and 0.031 m (point 4), and the average value σ_H was 0.012 m. In the case of variant V3, the standard deviation from the sample in relation to the average measured height assumed values from 0.007 m (point 3) to 0.020 m (point 8). The average value σ_H for the V3 variant was 0.010 m. Thus, it can be seen that increasing the number of measurement epochs recorded over a point reduces the precision of the measurement. This is supported by the increased standard deviation values for the V2 variant (recording 30 measurement epochs) compared to the V1 variant (recording 15 measurement epochs). However, comparing heights with those determined by geometric levelling indicates that the height values obtained using the NRTK VRS technique are greater than those from the geometric levelling (Fig. 5). The average difference for the V1 variant is 0.01 m, and 0.02 m for the V2 and the V3. Whereas, the divergence of average height values from the heights obtained by the geometric levelling of the 8 analysed points characterises the V3 variant.

The basic descriptive statistics for the calculated dependent and independent elevation differences are presented in Table 1. The average values of elevations differences between the analysed points agree with each other regardless of the variant within ±0.02 m, and in most cases within ±0.01 m. Therefore, when assessing the accuracy of height determination based on NRTK measurements and in comparison with the precision levelling, the results are consistent with the values obtained by Dawidowicz [2013a]. Meanwhile, the obtained values of standard deviation from the sample of dependent elevation differences are in the range from 0.005 to 0.011 m for the V1 variant, from 0.011 to 0.032 m for the V2 variant, and from 0.010 to 0.022 m for the V3 variant. This indicates that the lowest variability of dependent elevation differences is characterised by the V1 variant, and the largest by the V2 variant. As can easily be seen with the V3 variant, the range of standard deviation values from a sample of dependent elevation differences is exactly twice as large as with the V1 variant. Thus, in the analysed measurement variants, no significant changes can be observed in the average values of the obtained elevation differences, as also noted by Bae et al. [2015] analysing the average values of ellipsoidal height errors also obtained from NRTK measurements. At the same time, the analysed variants do not show that the variance of the obtained elevation differences is inversely proportional to the length of the measurement time, as demonstrated by Bae et al. [2015]. However, this may be due to too short measurement time at the point as well as too small differences in measurement time between the V1 variant and the V2 and V3 variants. However, when analysing the extreme values of the calculated dependent elevation differences in relation to a measurement variant, it was found that for the V1 variant the average difference between the extreme values of the same dependent elevation is 0.04 m, for the V2 variant – 0.08 m, and for the V3 variant – 0.07 m. In the case of the V1 variant, the sum of the calculated average dependent elevations is 0.000 m, and in the case of the V2 and V3 variants 0.001 m.

Table 1. The profile of designated dependent and independent elevation differences in relation to the measurement variant

ΔH	Variant	Dependent determinations (I = 225)				Independent determinations (I = 7)			
		ΔH_{avr}	σΔH	ΔH_{max}	Δh_{min}	ΔH_{avr}	σΔH	ΔH_{max}	ΔH_{min}
1–2	V1	1.624	0.010	1.652	1.604	1.625	0.008	1.630	1.613
	V2	1.635	0.018	1.668	1.579	1.618	0.018	1.631	1.579
	V3	1.623	0.013	1.654	1.582	1.628	0.013	1.643	1.611
2–3	V1	0.438	0.005	0.449	0.423	0.441	0.003	0.445	0.437
	V2	0.422	0.014	0.470	0.396	0.410	0.006	0.415	0.402
	V3	0.441	0.010	0.467	0.419	0.437	0.004	0.442	0.433
3–4	V1	1.263	0.007	1.281	1.248	1.271	0.007	1.281	1.262
	V2	1.289	0.032	1.391	1.247	1.293	0.042	1.359	1.248
	V3	1.262	0.010	1.286	1.234	1.260	0.005	1.269	1.255
4–5	V1	1.685	0.007	1.702	1.669	1.691	0.006	1.702	1.681
	V2	1.698	0.031	1.735	1.596	1.701	0.007	1.707	1.692
	V3	1.700	0.013	1.732	1.666	1.699	0.011	1.717	1.680
5–6	V1	–1.987	0.006	–1.973	–2.007	–1.985	0.004	–1.979	–1.990
	V2	–2.018	0.011	–1.989	–2.035	–2.025	0.006	–2.016	–2.033
	V3	–2.006	0.013	–1.975	–2.036	–2.012	0.014	–1.985	–2.027
6–7	V1	–0.358	0.007	–0.338	–0.373	–0.358	0.006	–0.350	–0.366
	V2	–0.360	0.013	–0.338	–0.388	–0.348	0.007	–0.342	–0.360
	V3	–0.361	0.013	–0.334	–0.395	–0.360	0.010	–0.349	–0.375
7–8	V1	–2.752	0.008	–2.734	–2.77	–2.748	0.006	–2.739	–2.756
	V2	–2.732	0.012	–2.707	–2.757	–2.721	0.004	–2.713	–2.726
	V3	–2.743	0.022	–2.689	–2.795	–2.738	0.022	–2.700	–2.766
8–1	V1	0.087	0.011	0.112	0.055	0.094	0.010	0.108	0.080
	V2	0.067	0.017	0.099	0.033	0.054	0.010	0.072	0.045
	V3	0.085	0.022	0.150	0.034	0.084	0.022	0.114	0.062

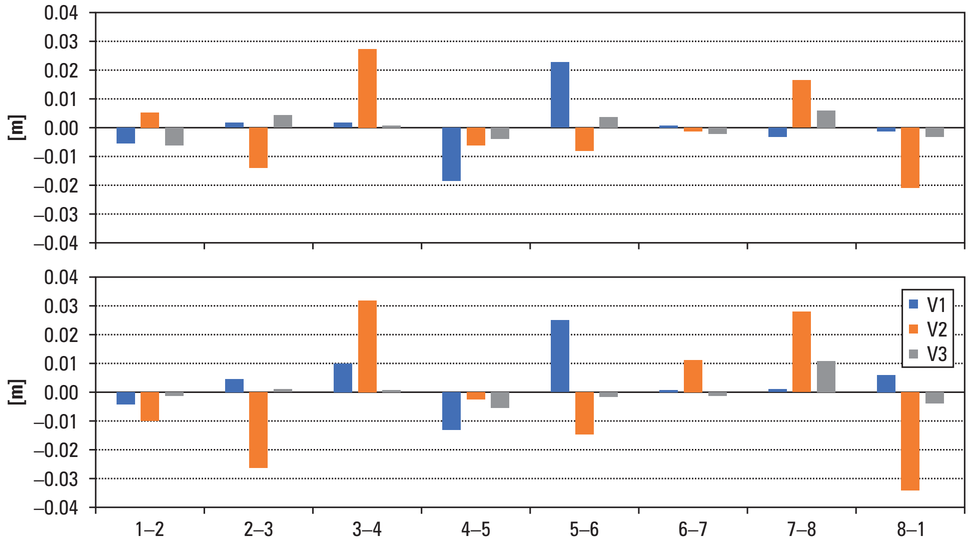
The range of values of calculated elevation differences depending on the measurement variant is presented in Figure 6. The largest range of calculated values of dependent elevation differences occurred in the levelling section of the V2 variant between points 3 and 4 (1.444 m) and points 4 and 5 (0.139 m) – in other cases it did not exceed the value of 0.10m. However, the largest value range of dependent elevation differences for the V1 variant was recorded at the levelling section between points 8 and 1 (0.057 m), the remaining cases did not exceed the value of 0.05m, which is achievable when the height is defined using NRTK measurements with the VRS correction [Garrido et al. 2011]. The range between the calculated values of dependent elevation differences for the variant V2 assumed the highest values at the section between points 7 and 8 (0.106 m) and 8 and 1 (0.116 m). In other cases, the ranges of dependent elevation differences for the analysed sections did not exceed 0.10 m. Due to the declared value of the accuracy of the used NRTK service, the range of results should not exceed 0.10 m, because the heights of start and end points should be identified with an accuracy of ±0.05 m. The values of the range of calculated independent elevation differences assumed significantly lower values than those of dependent elevation differences. The value range of independent elevations exceeded 0.10 m only in one levelling section (between points 3 and 4) and only for the V2 measurement variant.



Source: Authors' own study

Fig. 6. The difference between the maximum and minimum value of the obtained dependent (top) and independent (bottom) elevation differences depending on the measurement variant

The obtained values of the average dependent elevation differences were compared with the values of elevation differences derived from the measurement using the precise geometric levelling method. The deviation of the values of the calculated dependent and independent elevation differences of the reference values is presented in Figure 7.



Source: Authors' own study

Fig. 7. The deviation of the values of the calculated dependent elevation differences (up) and independent elevation differences (down) from the reference values of precise geometric levelling

The largest average absolute differences occurred in the V2 measurement variant, and the smallest in the V3, and then the V1. The deviations of the values of dependent elevations in the V3 variant did not exceed 0.006 m, while in the case of the V2 variant, their values were between 0.001 and 0.028 m, and for the V1 variant the differences ranged from 0.001 to 0.023 m. The maximum values of the differences in the V2 variant were recorded in the dependent elevation differences determined between points 3 and 4 (0.028 m), and for the V1 variant between points 5 and 6 (0.023 m). The range of calculated independent elevation differences from the reference value of V1 ranged from –0.013 to 0.025 m, while the largest differences of –0.034 to 0.032 m were recorded for the V2. The V3 variant showed the smallest differences from the reference elevation differences values, these values ranged from –0.005 to 0.011 m, which corresponds to the height difference values from the NRTK measurement and precision levelling that Dawidowicz [2013a] obtained.

When the elevation differences were calculated as an average of the 7 independently determined elevation differences of each levelling section, it was found that the sum of the elevation gains for the V1 was 0.031 m, for the V2: –0.018 m, and for the V3: –0.002 m.

4. Conclusions

Taking into account the current technological progress, the accuracy of vertical position in the national system of spatial references that is in force in Poland, supported by the services enabling measurements using the RTK or the NRTK technique and dual-frequency receivers, is declared as a value of ±0.05 m. A number of factors influence the correct determination of the height component of a position, from the observation conditions, the receiver class to the accuracy of the used quasi-geoid model.

As the conducted tests have shown, it is possible to determine the elevation differences between the points using the NRTK technique with an accuracy of 0.01 m. However, to ensure adequate accuracy, the elevation must be defined as the difference in measured heights, and should be determined several times based on independent measurements at the start and end of levelling section. The high accuracy and precision of the determined elevation differences from the heights measured by the NRTK and the VRS method is a consequence, to a large extent, of measuring a small area, and thus similar values of the sum of errors affecting the accuracy of the vertical position. Therefore, determining elevation differences as the differences of measured vertical positions leads to a reduction of some of the errors typical for the NRTK technique. The conducted measurement experiment allows to recommend the variant V3 for determining elevation differences, i.e. determining the coordinates of the start and end of levelling sections alternately and seven times by registering 30 measurement epochs at each point. Determining the height of the same point several times consecutively, as in V1 and V2, leads to correlated results characterised by high precision, but low accuracy. Determining the coordinate of the same point using the NRTK VRS technique at larger intervals improves the accuracy of the averaged height value, which also translates into the accuracy of determining the elevation value. Therefore, the measurement of the height measurement control network using the RTK and NRTK techniques should be carried out several times at greater intervals point by point in order to determine with high precision the elevation differences characterising the control network points. The determination of elevation differences using the NRTK VRS technique can be particularly effective in areas with large differences in height, where the determination of elevations using classical methods, i.e. geometric levelling using the "from centre" method, is time-consuming. The elevations determined in this way can be used to determine the height of the control network points with a better accuracy than ±0.05 m, when they are linked to the height point of the national network using classical methods, and to perform an alignment.

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