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ANALYSIS OF OBTAINING NORMAL HEIGHTS POINTS OF THE EARTH'S SURFACE USING DATA FROM SATELLITE MEASUREMENTS AND MODELS OF THE GEOID

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The paper presents the analysis of opportunities for normal heights points of the earth's surface using satellite data and global models of the Earth's gravity. The estimation accuracy of the geoid models EGM2008, EIGEN-6C4 on different height anomalies is calculated for points of geodesic network of educational and scientific polygon «Polotsk State University» on instrumental data and data models.

The final results of satellite measurements are spatial rectangular coordinates of the defined point in geocentric common terrestrial system of coordinates WGS-84. These coordinates are known formulas strictly converted to geodetic coordinates WGS-84 system: latitude B, longitude L, geodetic height H. Further transformation of the spatial coordinates of the common terrestrial WGS-84 coordinate system into other systems (SC-42, SC-95) is performed using seven transition options: ΔX, ΔY, ΔZ-linear parameters shift systems; ωX, ωY, ωZ-angle settings turn systems; m-scaling factor.

However, flat rectangular coordinates projected Gauss-Kruger and normal heights are common in the practice of topographic and geodesic works. Today the possibility of obtaining normal heights according to GNSS-measurements with an accuracy satisfying to large-scale surveys and other types of geodetic works is urgent for Belarus.

According to the theory of Molodensky geodetic height H is the sum of terms: the distance from the reference ellipsoid to the surface quasigeoid (height anomalies ζ) and the distance from the surface quasigeoid to the corresponding point on the Earth's surface (normal height H^{γ}) [1]

$$H = H^{\gamma} + \zeta, \quad (1)$$

Currently, the most accurate for practical application are geoid models EGM2008, EIGEN-6C4, by the National Geospatial-Intelligence Agency – NGA and International Centre for Global Earth Models – ICGEM respectively. These geoid models have a full set of harmonic coefficients of the geopotential up to 2190-th degree [2].

It is known that the normal height assigned to the surface quasigeoid and gravity model of Earth carry information about the geoid. Therefore the translation of geodetic heights into the normal height using data from a geoid model contains an error. This error is the deviation from the geoid quasigeoid at this point. Strictly speaking, the geoid models provide orthometric heights instead of the normal. However, the practical interest is the possibility of normal height according to the GNSS-measurements and gravity models.

In this article the analysis of a possibility of obtaining normal heights according to satellite measurements and models of geoids of EGM2008 and EIGEN-6C4 is made. The study was performed according to the differences of height anomalies calculated for the ten points of scientific-training polygon "Polotsk State University."

For obtaining anomalies of heights GNSS measurement using dual frequency satellite receivers Trimble R7 Zephyr Geodesic and geometric levelling of class III were performed by the authors.

Anomalies of heights on geodesic points are received on gravitational models of Earth EGM2008, EIGEN-6C4 with the use of Calculation Service International Centre for Global Earth Models – ICGEM) [2]. The values of anomalies of heights obtained by the gravity model are shown in Table 1. Location scheme of geodesic points on the scientific-training polygon is shown in Figure 1.

Table 1 – The values of anomalies of heights obtained by the gravity model

Point ID	EGM2008 2190	EIGEN-6C4 (2014) 2190
1	2	3
1001	20,525	20,565
1002	20,522	20,562
1004	20,520	20,560
1005	20,520	20,560
1005	20,521	20,561
1006	20,512	20,552

Table 1 Conclusion

1	2	3
101	20,528	20,568
102	20,487	20,527
103	20,547	20,587
104	20,539	20,580
105	20,540	20,580

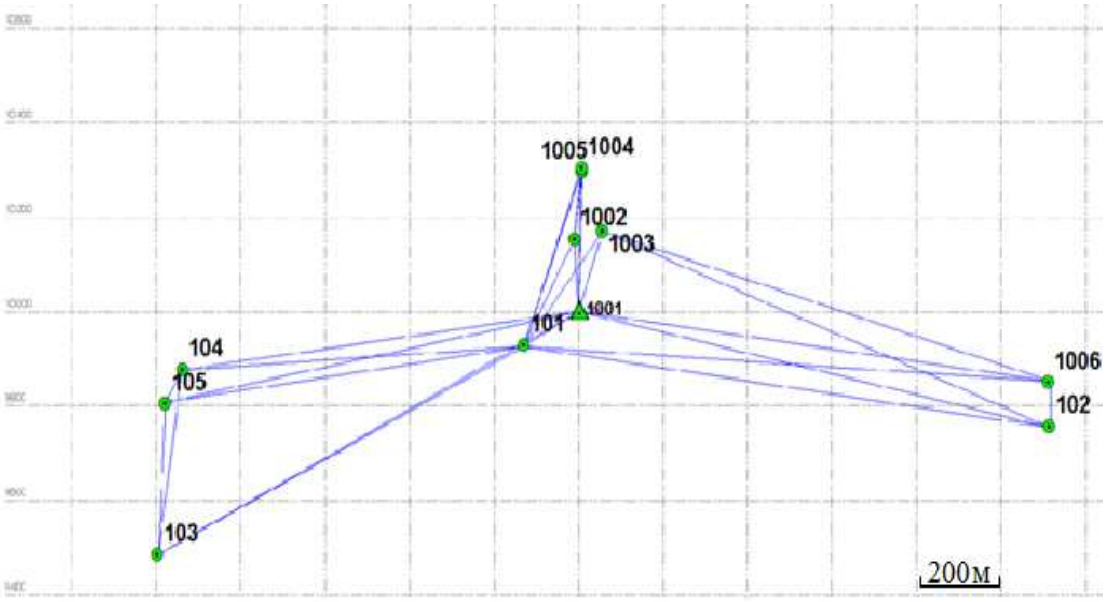

Fig. 1. Scheme of geodesic points on the scientific-training polygon

Information about anomalies heights using GNSS-measurement results (2015) was derived by comparing the difference in the geodesic height between reference points and datum profile № 1001, with elevations between the same reference points found from the geometrical levelling of class III. Excess should be regarded as the difference between normal heights and reference points. Thus, the anomaly height was determined according to formula (2) [3]:

$$\zeta_I = (H_I - H_{№1001}) - \sum_{№1001}^{I} h, \quad (2)$$

where ζ_I – is the anomaly of height in the current reference frame relative to reference point № 1001;

H_I and H_{1001} – is the geodesic height respectively of the current reference point and the profile of frame №1001, obtained from satellite data;

Σh – is the total excess between bench mark №1001 to the current bench mark, obtained from geometric height measurement.

The values of the height anomalies a relatively point №1001, obtained by the results of GNSS measurements and geometric levelling, and also according to the data of gravitational models of the Earth presented in Table 2.

Table 2 – Values of height anomalies at relative point №1001

Names of points	1001	1002	1004	1005	1006	1006	101	102	103	104	105
EGM2008, m	0	-0,003	-0,005	-0,005	-0,004	-0,013	0,003	-0,038	0,022	0,014	0,015
EIGEN-6C4, m	0	-0,003	-0,005	-0,005	-0,004	-0,013	0,003	-0,038	0,022	0,015	0,015
GPS-geometric levelling, m	0	-0,015	-0,009	-0,001	-0,011	-0,071	0,012	-0,036	0,019	0,051	0,021

Based on the values of the anomalies of height, it can be noted that the models of the geoid EGM2008 and EIGEN-6C4 have the same shape in this part of the surface and the systematic displacement relative to each other.

For these geodesic points statistical processing of the different values of height anomaly was conducted, derived from models EGM2008, EIGEN-6C4 and height anomaly, obtained according to data instrumental researches. Results of processing are presented in Table 3.

Table 3 – Statistical processing of the different values anomalies of height

Deviations	EGM2008 model in comparison with GPS measurements and geometric leveling	EIGEN-6C4 model in comparison with GPS measurements and geometric leveling
[Δ]/n, m	0,0026	0,0027
+Δ, max, m	0,058	0,058
-Δ, max, m	-0,037	-0,036
RMS, m	**0,0225**	**0,0223**

Based on the statistical analysis of the data it can be noted that the law of distribution of the differences of the anomalies of height is close to normal. RMS error getting altitude anomalies does not exceed the values given by the creators of the models [2]. It should be noted that gravitational models have a systematic displacement relative to each other by the absolute values of the anomalies of heights (σ≈40mm), however the forms of the geoid surface on the area are the same. The presence of systematic displacement models relative to each other causes difficulty in choosing a geoid model, if necessary, obtaining the absolute elevations of points in the system of normal heights. However, this error can be completely eliminated in the presence of at least one point from the level in the system of normal heights determined by using geometrical levelling.

Figure 2 presents the isolines of deviations of geoid model anomaly height EIGEN-6C4 on instrumental data results (relative to geodetic points №1001).

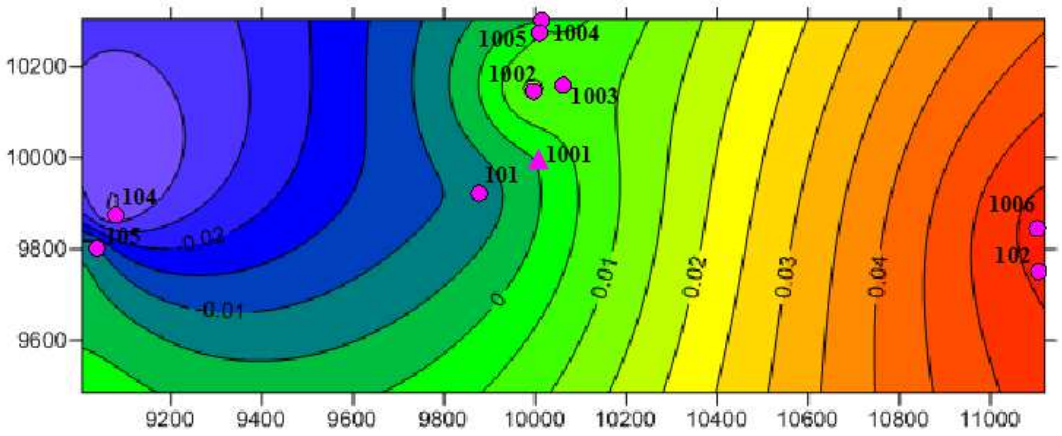

Fig. 2. Scheme of deviations height anomalies of geoid EIGEN-6C4 by anomalies obtained according to the data of GNSS measurements and the results of geometric levelling (isoline interval of 0.005 m)

Comparing the height anomalies, obtained both by using gravity models, and using the combination of GNSS measurements and geometric levelling can be argued that the data of the model have good convergence with the results of instrumental data, which is confirmed by other studies [4,5,6]. In addition, a small area geoid models EGM2008 and EIGEN-6C4 have the same shape, the same is confirmed by the difference in anomalies of height. Evaluation of the accuracy of the normal heights using geoid model EGM-2008, EIGEN-6C4 has shown that the use of these models of geoid heights in the territory for the determination of normal heights is only possible when creating a shooting justification to perform surveys with contour interval of at least 1 m [7].

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