MODELLING THE QUASIGEOID FOR THE PRUT-BARLAD HYDROGRAPHICAL BASIN AREA

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Abstract: *The studies of the hydrographic basins areas are an import activity regarding the prevention of the natural disasters. The geodetics works supposed to determine the digital elevation model to be used then in hydraulic analyses applications. A crucial support , not only for the GNSS determinations but also for the LiDAR and orthophotomap production is represented by the model of the quasigeoid for the studied area that can be used for the conversion of the ellipsoidal altitudes determined with GNSS technology into the national altimetric reference system. In this paper is presented a study case for the modelling of the quaisgeoid in the Prut-Barlad hydrographical basin area using the geometric method. There were made GNSS static observations and precise leveling measurements for the points of the thickening network. An application in Matlab software was developed for the correction of the European quasigeoid model EGG97.*

Keywords: *quasigeoid, GNSS, leveling, geometric modelling, Matlab, EGG97*

1. Introduction

The coordinates resulted from the GNSS measurements in the ETRS89 system have to be transformed into the national reference systems. If the planimetric problem is solved using the official transformation of the TransDatRO application the height transformation remains an important problem when we talk about large areas and precise transformation of the ellipsoidal heights into normal heights of the national reference system with "0" fundamental point Black Sea 1975. To model a precise local quasigeoid remains the only solution in this case. This paper contains a description of the procedure followed to model a precise quasigeoid model for the Prut–Barlad hydrographical basin.

2. General considerations

In Romania, the situation of the determination of a quasigeoid is debated in more specialist reunions. Till now, in Romania, there is not developed a quasigeoid model that could assure high precision for the determination made with modern GNSS technology and trans calculate the ellipsoidal heights in national reference altitude system [6].

In 2009 it was issued the Order no. 212/4.05. 2009, of the General director of ANCPI for adoption in Romania of the European Terrestrial Reference System 1989, which consists of ETRS89 geodetic datum based on GRS80 ellipsoid (Geodetic Reference System 1980 - Geodetic Reference System 1980) and ellipsoidal geodetic coordinate system.

A quasi geoid modeling is the determination (interpolating) of a conversion between altitudes, ellipsoidal surfaces and normal altitudes, modeling abnormalities altitude values in irregular network points as described by thickening geodetic network. Geometric methods are known by using multivariate methods (polynomials of degree higher, Delaunay triangulation, Ponder the inverse distance, nearest neighbor or natural neighbor) or by correcting an existing model by making new precision measurements [5].

The quasigeoid grid can be defined by a file containing coordinates of the knots and the values of the anomaly of the altitude interpolated in each node. The quasigeoid grid step is chosen according to accuracy and needs [6].

In order to interpolate altitude anomalies in the created quasigeoid model, there can be used several methods including the most simple and easy to implement in applications that are specifically designed bilinear interpolation bicubic spline interpolation 2D (creates smooth surfaces) [2].

3. Modelling the quasigeoid for the Prut-Barlad hydrographical basin aria

As mentioned, the determination of a quasigeoid model is one of the most important activities in the field of geodesy. Once determined the quasigeoid model using the results of high precision and GNSS measurements made with modern technology can lead to accurate determination of the altitude in the national reference system.

Given that, the levelling precision determinations for any point on the Earth's surface is long lasting activities, the only option for determine normal altitudes (national reference system) from GNSS measurements is using an interpolated quasigeoid model.

After interpolation in the quasigeoid model the anomalies of the altitudes are obtained, which, as noted, may decrease the values of precision of the ellipsoidal altitudes determined by GNSS technology to achieve altitude values in national reference system. In this way, the geometrical method of geoid generation could be used.

The geometrical method for the determination of the anomaly of the altitude assumes the following mathematic relation:

$$\zeta_i = h_i - H_i \qquad , \text{i – considered point} \tag{1}$$

where the difference between the ellipsoidal altitude and normal altitude represents the anomaly of the altitude.

Determination of the altitudes in ETRS89 reference system was achieved with GNSS technology, in points of Romanian Leveling Network that were stationed directly with GNSS equipment and where it was not possible (benchmark embedded in bridges, churches and other buildings) was made by geometric leveling from new point located nearby.

From processing the bridging network consisting of 76 points determined by GNSS technology (static method), the determination of geometric leveling for leveling control points which were not GNSS stationed and for which new points were materialized and which underlying the quasigeoid surface model generation, these values of altitude anomaly were determined. These will form the basis for the quasigeoid generation in the interest area.

For the determination of the surface model, there were used the quasigeoid altitudes anomaly values for the considered points. Because only a geometrical modeling is not sufficient to generate a quasigeoid surface with adequate precision, it was used and the European gravity geoid model EGG97. The European model correction EGG97 anomaly with

values determined from GNSS measurements altitude and leveling will be generating a surface model for the quasi gravimetric work.

The designed points to be measured by GNSS technology and geometric precision leveling have the following position as shown in Fig.1:
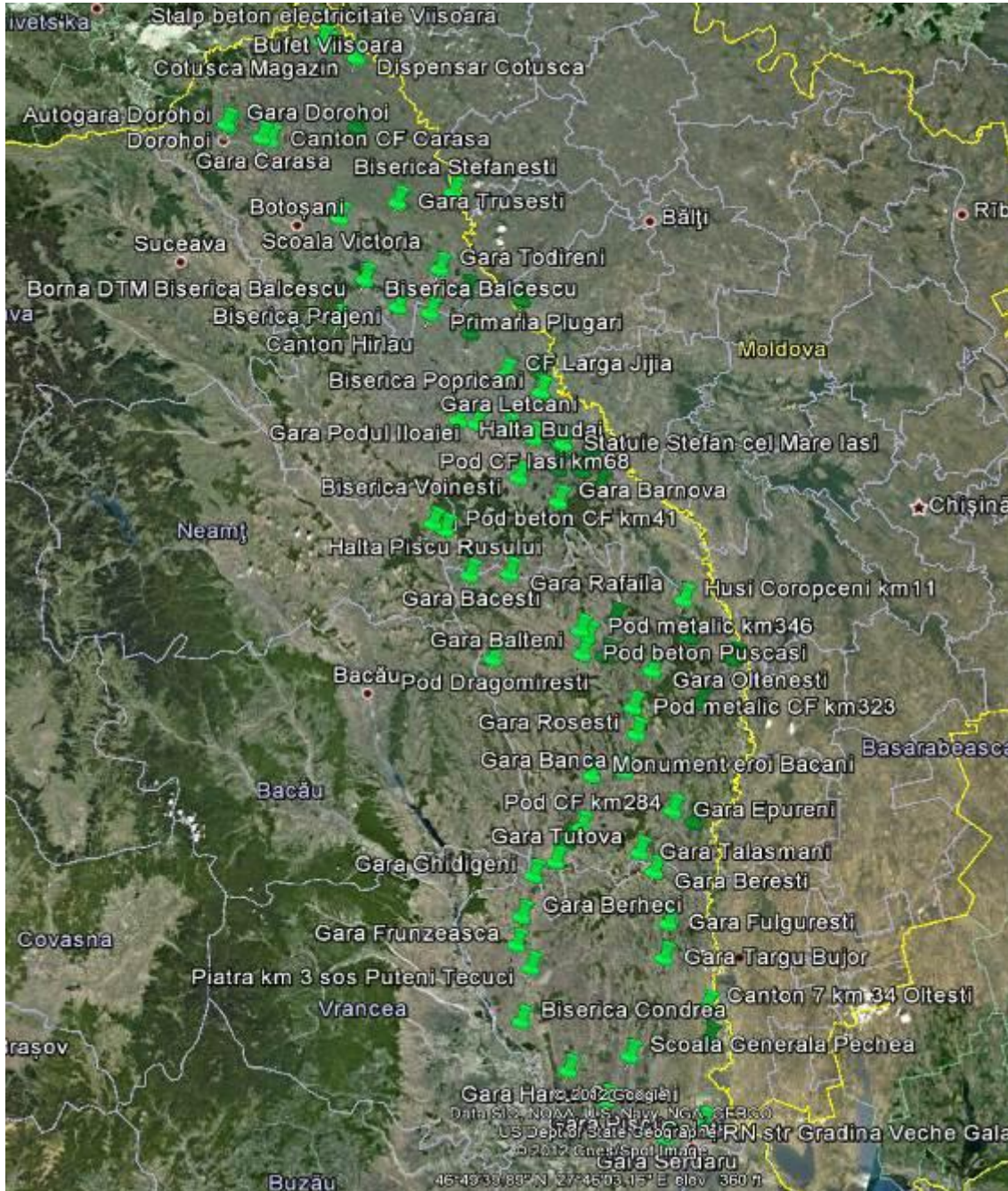

Fig.1 Position of the points measured for quasigeoid modeling

The solution was to correct the quasigeoid EGG97 model and interpolate the surface anomaly differences between the values determined from GNSS measurements and precise leveling and interpolated values in the model EGG97 anomaly. For the inside perimeter points determined by the underlying approach to creating model generation is the bicubic spline interpolation using triangulation with finite element method. For areas outside the perimeter the nearest neighbor method was used.

Table 1. Differences between the anomaly of the altitude of EGG97 model and the GNSS and leveling measurements

Point	Ellipsoidal altitude ETRS89 h (m)	Normal altitude Black Sea 1975 H (m)	Anomaly of the altitude GNSS – precise levelling (m)	Anomaly of the altitude ζ EGG97 (m)	Differences ζ (m)
Autogara Dorohoi	187.872	154.335	33.537	33.968	-0.431
Biserica Balcescu	181.323	147.892	33.431	33.703	-0.272
Biserica Bivolari	96.106	63.838	32.268	33.057	-0.789
………………..	………..	………….	………….	……….	………..

To model the quasigeoid were used 54 points of the 76 evenly distributed over the entire work area with ellipsoidal altitudes determined in ETRS89 reference system and in normal national reference system with fundamental zero point Black Sea 1975, as well as altitude anomaly values interpolated in European geoid model EGG97[7][8].

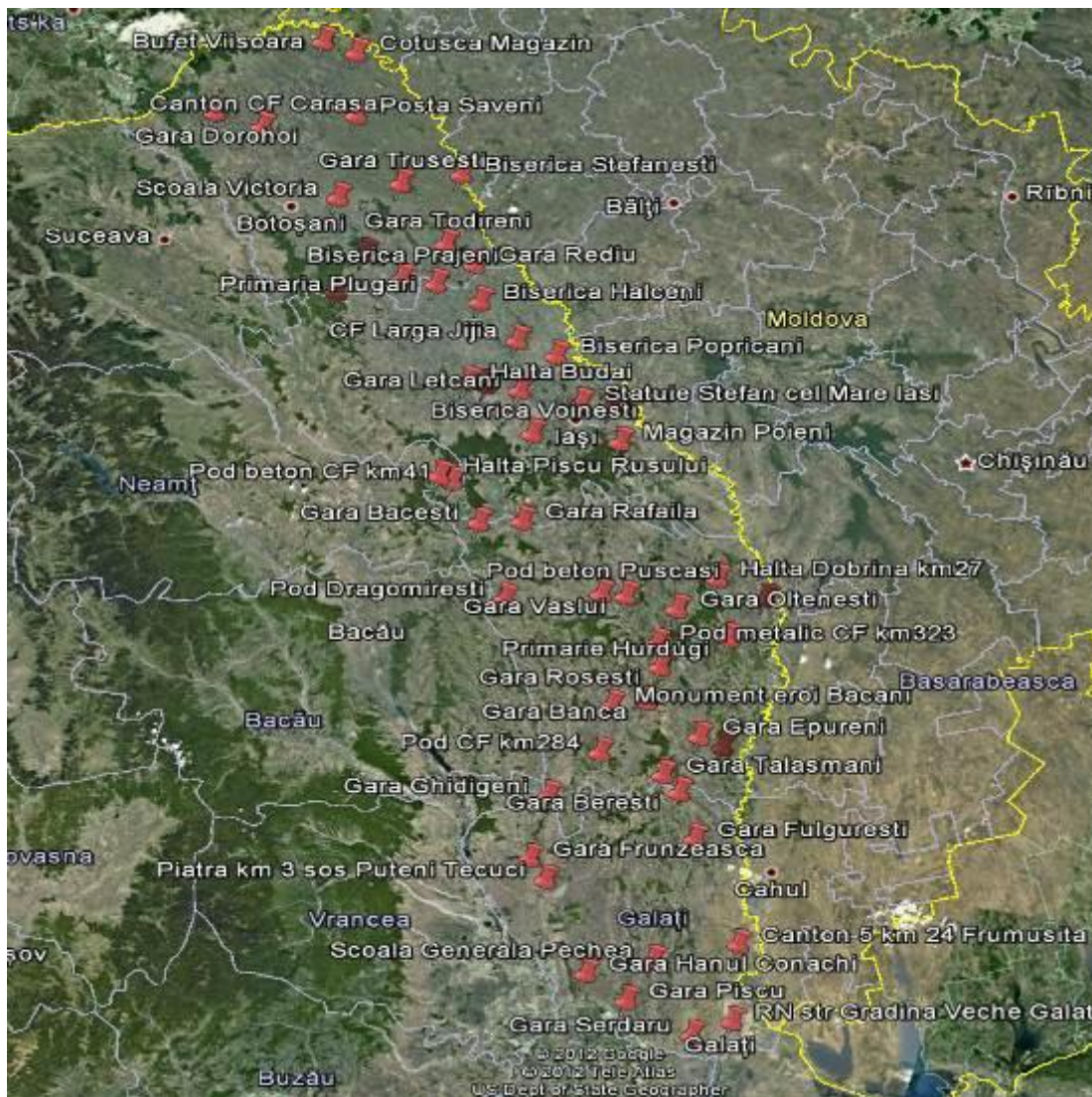The position of the points is represented in the following figure (Fig. 2):

Fig.2 Position of the points used in quasigeoid modeling

A completely new approach regarding the determination of the quasigeoid model on the hydrographical aria of Prut Barlad basin is represented by the utilisation of the anomalies of the altitude obtained by interpolating the European EGG97 regional model that will be corrected with the values of the anomaly of the altitude determined by GNSS and levelling measurements. The European quasigeoid model is a gravimetric one, so through its correction with determinations of the anomaly of the altitude from GNSS and levelling measurements it will be obtain a quasigravimetric conversion surface.

The solution it was computed for a grid spacing of the quasigeoid model (dN=dE=1080m, planimetric coordinates), following multiple steps.

The determination of the anomaly of the altitudes corrections in points of the scattered data set is realised with the relation:
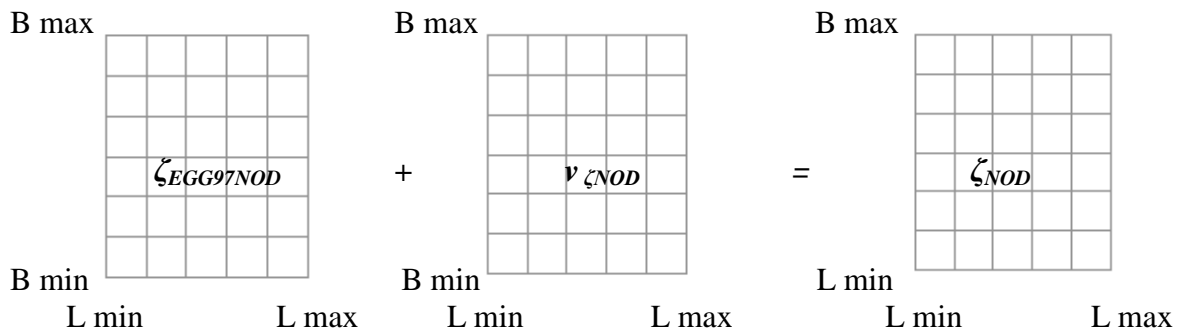
$$v_{i\zeta} = \zeta_{iETRS89-Niv} - \zeta_{iEGG97} \tag{2}$$

where: v_ζ – the vector of the differences for the anomaly of the altitude

$\zeta_{ETRS89-Niv}$ - the vector of the anomaly of the altitude from GNSS and levelling measurements

ζ_{EGG97} – the vector of the anomaly of the altitude from the interpolation into the European EGG97 model

Then was realised the correction of the European GG97 model with the grid containing the v_ζ correction values to obtain the quasigeoid grid on the aria of interest (hydrographical basin of Prut Barlad rives), ζ_{NOD}.

B max

$\zeta_{EGG97NOD}$

B min

L min   L max

+

B max

$v_{\zeta NOD}$

B min

L min   L max

=

B max

ζ_{NOD}

L min

L min   L max

The surface obtained after the interpolation of the correction of the anomaly of the altitude differences is presented in the following figure (Fig.3):
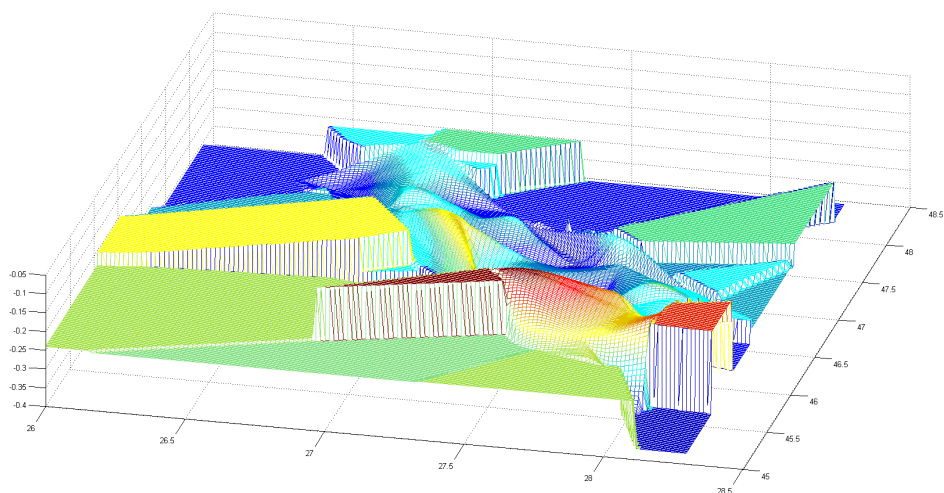

Fig. 3 Correction surface resulted after interpolation (3D view)

After modeling the quasigeoid surface the interpolated surface result as a rectangular grid with nodes containing its altitude anomaly values.

To determine the altitude anomalies in quasi geoid model is determined using bilinear interpolation on regular grid.

Some features of the following grid (grid generation format is consistent with the national scheme have reference standards and regulations in force and is compatible with the application you wish TransDatRO its use interpolation method implemented in the application):

Minimum latitude: 45.00 (d.ddd)
Maximum latitude: 48.30 (d.ddd)
Minimum longitude: 26.00 (d.ddd)
Maximum longitude: 28.30 (d.ddd)
Step on latitude: 0.010 (d.ddd) – aprox.1080m
Step on longitude: 0.015 (d.ddd) – aprox. 1080m
The sense in grid: colum1: min Lat -> max Lat, min Long; colum2 min Lat - > max Lat, min Long +dLong ; colum3 ……
No. of grid nodes: 50974 (331 lines * 154 columns)
Example of the grid:

Table 2. Example of the quasigeoid grid

Nr. Nod	Latitude	Longitude	Anomaly of the altitude
1	45.000	26.000	33.285
2	45.010	26.000	33.298
3	45.020	26.000	33.312
…………	……………..	…………………	…………..

Representation of quasigeoid model determined for the aria of interest is shown in the following figure:
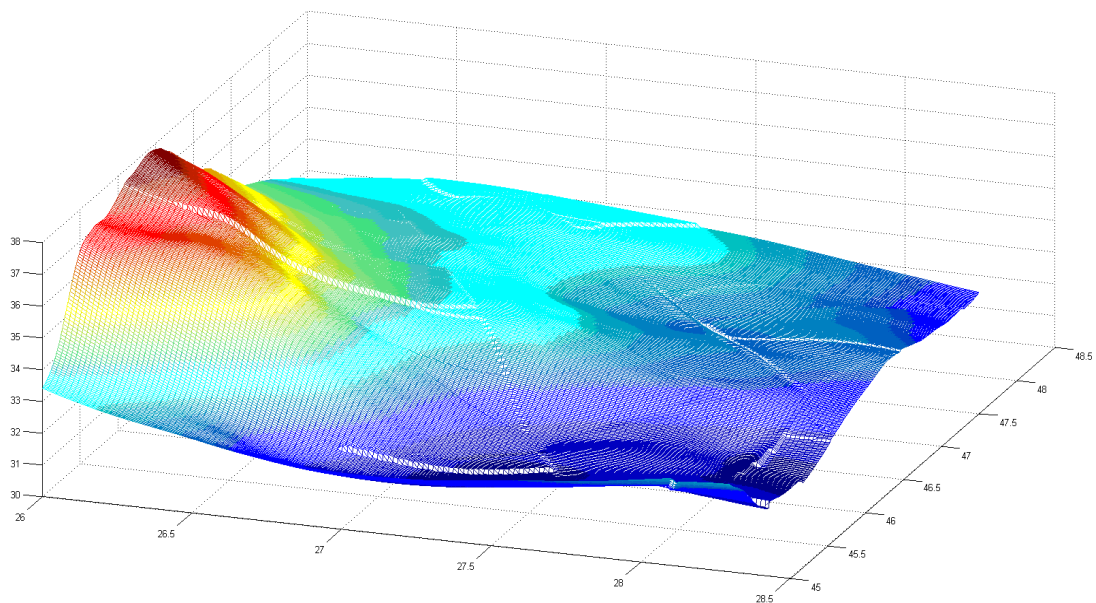

Fig.4 3D representation of the quasigeoid model in Prut-Barlad basin aria

Checking the model was based on points whose coordinates in the system of reference ETRS89 (new determinations GNSS) and the national reference system normally Black Sea 1975, ed.1990 (new geometric leveling measurements) are known and not used in the creation of the model mentioned above (11 points). After checking the model were obtained the following results:

Table 3. Checking the quasigeoid model

Point	Ellipsoidal altitude	Normal altitude	Normal altitude quasigeoid model	Differences
Autogara Dorohoi	187.872	154.335	154.266	0.069
Canton 7 km 34 Oltesti	39.138	8.168	8.135	0.033
Gara Balteni	133.089	100.647	100.702	-0.055
Gara Barnova	284.013	251.486	251.466	0.020
Gara Berheci	78.487	47.412	47.417	-0.005
Gara Ciurea	97.086	64.663	64.626	0.037
Gara Targu Bujor	68.883	37.862	37.844	0.018
Gara Tutova	87.788	56.661	56.595	0.066
Pod CF Iasi km68	77.264	44.837	44.801	0.036
Pod metalic km346	133.316	100.916	100.974	-0.058
Pod Piatra Iasi	77.098	44.694	44.688	0.006
Scoala Generala Badeana	92.012	60.819	60.716	0.103
Scoala Generala Carniceni	97.325	64.883	64.818	0.065
Stalp beton electricitate Viisoara	217.883	184.290	184.292	-0.002
Zid canal apa Paun	352.684	320.226	320.233	-0.007

After checking, the average difference is approximately + / - 0.030 m with a mean square error of + / - 2mm.

4. Conclusions

As mentioned, the determination of the quasigeoid model is one of the most important activities in geodesy. Once determined a quasigeoid model using the results of high precision GNSS measurements made with modern technology can lead to accurate determination of altitudes in the national altimetric reference system.

Since the measurements of precise leveling for any point on Earth's surface is long term activities, the only option for normal altitudes determinations (national reference system) with GNSS measurements is to use an interpolation into a quasigeoid model.

All GNSS measurements performed for the determination of the coordinates of the network points (the thickening network) will be made using the altitudes in the national system. Also, any leveling of detail through modern technology using GNSS DGNSS / RTK using differential corrections in real time or post processing, from a fixed base that transmits

corrections via radio (UHF radio modem) or using differential corrections from the Romanian ROMPOS position determination system can lead to high precision results from applying the interpolated solutions of quasigeoid model created to determine normal altitudes.

Determination of the quasigeoid model is a crucial stage in the network regardless of geodetic surveying work performed and any leveling methods used.

Since hand equipment and other new technologies in the topographic measurements cannot determine altitudes in the national reference system for the determinations of the ground checking points for photogrammetric or LIDAR projects or the generation of altimetric Digital Terrain Model without using a precise quasigeoid model based on a sufficient number of GNSS and leveling points will ensure high accuracy for determining altitudes in the national reference system.

The generated model could be improved through the utilization of other methods or by their combination and using the regional (European EGG97 or EGG08) model or global (EGM2008 model) [1],[3].

5. References

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