Determination of a New Gravimetric Quasigeoid for Romania

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SUMMARY

The project of modeling a gravimetric quasigeoid for Romania is carried out in stages, based on the gravimetric measurements in the area of each county, in the gravimetric points of the 0, 1st and 2nd order gravimetric network, in the checkpoints (with GNSS/levelling data) and also in the new designed points to ensure a uniform density and distribution of these points in order to generate the quasigeoid model.
The new local quasigeoid model obtained from the measured points will improve the height transformation grid (Avramiuc, Dragomir, Rus, 2009), ensuring the transition from the Black Sea 1975 normal height system to the European Terrestrial Reference System - ETRS89 ellipsoidal height which is provided through the Romanian Position Determination System - ROMPOS. The new gravimetric quasigeoid model will be more accurate than the current geometric quasigeoid, ensuring the interoperability of national and European spatial data in the Infrastructure for Spatial Information in the European Community - INSPIRE, for the adoption and implementation of European standards for scientific purposes and for solving technical problems such as support for economic activities.
The remove-compute-restore technique was used to remove the long-wavelength component from the Global Geopotential Model (GGM) and the effect of the short-wavelength signal by applying terrain corrections, to compute residual geoid heights, and to restore the effect of the GGM and topography.
In this article are presented the main activities that took place in the period 2016-2021 for creating the projects in the counties of Romania and the results obtained till now as well as the perspective for the next years.

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1. INTRODUCTION

In Romania, over the years, geodetic specialists have made efforts to determine some quasigeoid models at the level of the entire national territory or at the local level based on existing data and available resources. Quasigeoid models have been developed in isolated projects, in most cases being the subject of doctoral dissertations or research topics (Mihailescu, 1974, Marinescu, Tomoioaga, 1998, Rus, 2000, Spiroiu, 2005, Sorta, 2013). Based on GNSS and leveling determinations, a geometric quasi-asteroid was initially determined (Tenzer, Prutkin, Klees, Rus, Avramiuc, 2008) which was later improved and included in the transformation of altitudes at the national level.

In 2014, it was adopted the measure HB 13 of the Institutional Strategic Plan, approved by Order no. 763/16.05.2014 of the Minister of Regional Development and Public Administration on the rehabilitation and modernization of the National Geodetic Precision Leveling Network by determining a quasigeoid for Romania, following the strategy of the National Center for Cartography (NCC).

In the project, NCC will perform relative gravimetric measurements on the gravimetric points from the National Gravimetric Network for the transmission of gravity to the new determined points, on the checkpoints and control points in which geometric leveling determinations and GNSS determinations have been done within the project "Rehabilitation of the leveling precision network Ist and IInd order through recognition and GNSS determinations in specific points", consistent with class D National Geodetic Network (NGN) or the NGN class B and C. The project aims to improve the transformation grid on altitudes and to improve the digital elevation model and orthophoto map through which Romania's topographical reference plan (TOPRO 5) is updated – support for the implementation of the National Programme for Cadaster and Land Registry and for carrying the acceptance of works for registration of real estates in the land registry. An accurate 3D geospatial network will provide support and control for the implementation of advanced technologies in order to get the cadastral plans in cities/municipalities, by LIDAR flying and digital photogrammetric restitution.

2. MATERIALS AND METHOD

For performing gravimetric measurements during the projects were used Scintrex relative gravimeters - Autograv CG5 with 1 microGal reading resolution and Scintrex - Autograv CG6 with 0.1 microGal reading resolution.

In order to achieve the adjustment of the gravimetric measurements, the corrections necessary to reduce gravimeter readings were first applied.

Reduced gravimetric data were placed in a functional model comprising independent readings given by the following equation (Oja, 2008)

$$l(t) + v = g + N_0 + \Delta F(z) + D(t) \qquad (1)$$

in which:

- t - time measurement;
- l: reading the low value of the instrument;
- v: correction;
- g: gravity value of the station;
- N_0: a constant bias;
- ΔF(z): calibration function;
- z: reading gravimeter;
- *D(t):* gravimeter drift function

Assuming that there are n number of measurements, observation equations of the form (1) are written in the form of a matrix

$$\mathbf{L}^b + \mathbf{V} = \mathbf{AX}\text{, with the weighting matrix } \mathbf{P} \qquad (2)$$

where:

- $\mathbf{L^b}$: a vector containing the gravity measurements;
- **V**: a vector containing corrections;
- **A**: matrix coefficients;
- **X**: a vector containing the unknowns.

Using least-squares adjustment, the estimates of unknowns are obtained (Hwang, Cheinway, Cheng-Gi Wang, Li-Hua Lee, 2002)

$$\hat{\mathbf{X}} = (\mathbf{A}^T\mathbf{PA})^{-1}\mathbf{A}^T\mathbf{PL}^b \qquad (3)$$

and the a posteriori covariance matrix of $\hat{\mathbf{X}}$

$$\hat{\mathbf{\Sigma}}_{\hat{X}} = \hat{\sigma}_0^2(\mathbf{A}^T\mathbf{PA})^{-1} \qquad (4)$$

In order to statistically test the relevance of the adopted parameters, the Student test has been used, and in order to calculate a posteriori variance test χ^2 has been used. To test the existence of gross errors, test $\boldsymbol{\tau}$ (Alan J. Pope, 1976) and the matrix of the cofactors corrections Qvv have been used.

The new gravimetric quasi-geoid model for Romania will be done using the remove - compute – restore algorithm.

In step 'remove', represented by relation (5), the long-wavelength gravitational effects of a global geopotential model Δg_{GGM} (EGM08 / GOCE), and the high-frequency local terrain effects Δg_{RTM} are removed from the free air anomalies Δg_{FA}, resulting in smooth residual gravity anomalies Δg_{res}.

$$\Delta g_{res} = \Delta g_{FA} - \Delta g_{GGM} - \Delta g_{RTM} \qquad (5)$$

The effects of the terrain Δg_{RTM} are computed using the RTM approach (Forsberg, 1984) where only the topographic irregularities relative to a smooth mean height surface are taken into account.

The smooth surface can be constructed by low-pass filtering of the detailed DTM to transform it into a coarse and smooth topography grid. The RTM is given by (Forsberg 1984):

$$\Delta g_{RTM} = 2\pi G\rho\left(H - H_{ref}\right) - C_T \qquad (6)$$

where H_{ref} is the height of the smooth reference surface, and H is the height of the computation point respectively, and C_T is the classical terrain correction.

In the 'compute' step, the Stokes integral is applied to the residual gravity anomalies Δg_{res} to generate the residual height anomaly $\zeta_{\Delta g_{res}}$ using the Fast Fourier Transform - FFT (Kaminskis, Forsberg, 1996).

For this calculation, the implementation of GRAVSOFT's SPFOUR function (Forsberg, Tscherning, 2008) is used, according to relation (7), which removes the effects of any remaining long-wavelength harmonics.

$$S_{mod}(\psi) = S(\psi) - \sum_{n=2}^{N} \alpha(n) \frac{2n+1}{n-1} P_n cos\psi \qquad (7)$$

In the 'restore' step, the components removed in the first step are restored to the residual height anomaly $\zeta_{\Delta g_{res}}$, in the form of the height anomaly ζ_{GGM} computed from a global geopotential model (EGM08 / GOCE) and the height anomaly ζ_{RTM} as a result of the effects of the terrain. This process is presented according to equation (8).

$$\zeta = \zeta_{\Delta g_{rez}} + \zeta_{GGM} + \zeta_{RTM} \qquad (8)$$

Finally, the gravimetric height anomalies are corrected based on the geometric height anomalies obtained in the check and control points, determined with GNSS technology, and by geometric leveling measurements.

3. RESULTS AND DISCUSSIONS

The gravimetric quasigeoid is made entirely (including gravimetric measurements, GNSS determinations, geometric leveling measurements, data processing and quasigeoid determination) for the counties Bihor, Arad, Hunedoara, Cluj, Alba, Mureș, Sibiu, Harghita, Brașov, Covasna, Gorj, Dolj, Olt, Timis, Caras-Severin, Mehedinti and Teleorman, according to the situation presented in fig. 1. For 6 counties (Valcea, Arges, Dambovita, Prahova, Buzau and Giurgiu) the gravimetric works and data processing are completed, and the generated quasigeoid is in the testing phase.

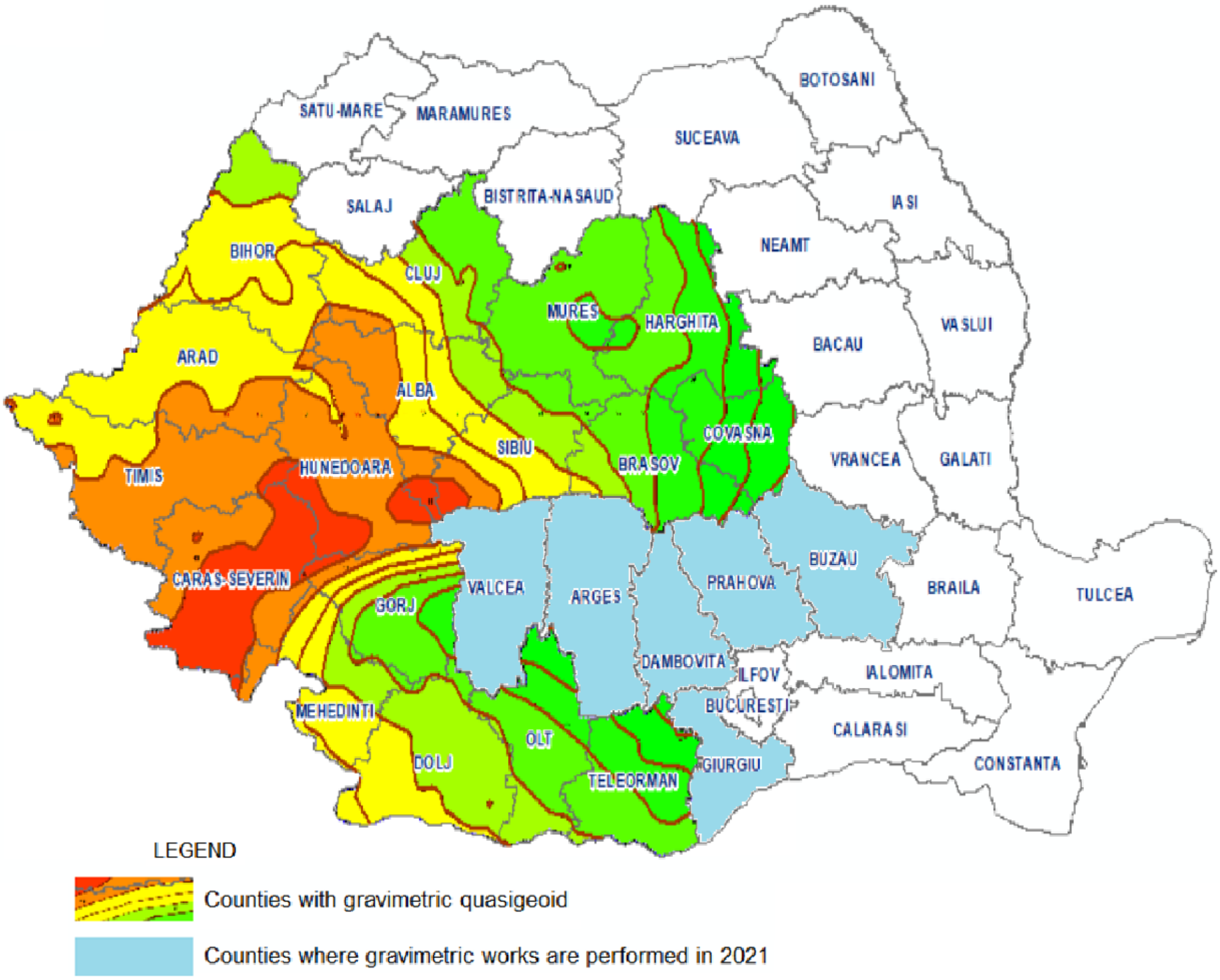

Fig. 1 - *The progress of the works for the determination of the quasigeoid for Romania*

The gravimetric quasigeoid was tested by computing and analyzing the differences $\Delta\zeta$ in the height anomalies using the relation (9)

$$\Delta\zeta = \zeta_{geom} - \zeta_{grav} \qquad (9)$$

where ζ_{geom} is the geometric height anomaly computed at the check and control points, and ζ_{grav} is the gravimetric height anomaly computed at the same points. The statistical situation of differences in height anomalies $\Delta\zeta$ is presented in Table 1.

Table 1. — *The statistical situation of differences in height anomalies*

Data	Mean [m]	Standard dev. [m]	Min. [m]	Max. [m]
1664 check and control points	-0.003	0.030	-0.153	0.167

4. CONCLUSIONS

The interpolation accuracy of the new points in the grid with the new gravimetric quasigeoid depends on the distribution of gravimetric points and check and control points, the accuracy of determining these points by gravimetric measurements, GNSS technology, and geometric leveling measurements, the accuracy of other data used to generate the quasigeoid. It is estimated that, for the counties illustrated in fig. 2 with the new gravimetric quasigeoid, the interpolation accuracy of the new points is around 10-12 cm.

To sum up, a more accurate coordinate transformation on altitudes will be provided, based on ellipsoidal altitudes gotten with GNSS technology and height anomalies to be interpolated from the new gravimetric quasigeoid, making important steps forwards, as well, to get a more accurate digital elevation model for the achievement of the orthophotomap and for carrying out the systematic cadastral activities included in the National Programme for Cadastre and Land Registration 2015-2023.

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BIOGRAPHICAL NOTES

Radu – Dan – Nicolae Crişan currently holds the position of Deputy Director of the National Center for Cartography. His main task is the technical and administrative management of specialized activities, coordination, guidance and control of geodesy and cartography works. Between 2005 and 2007 he was the Director of the Cadaster Department from the National Agency for Cadaster and Land Registration, since 2016 being highly involved in the project related to the determination of a new gravimetric quasigeoid for Romania. Also, Mr. Radu Crișan has held the position of Director of the National Center for Cartography between 1996 – 2001 and 2016 – 2021 and he achieved his Ph.D. in Geodesy in 2001.

Irina Belinschi is employed as a Cadaster Counselor at the National Center for Cartography since 2019 and she is involved in multiple projects including the data processing and determination of a new gravimetric quasigeoid for Romania.

Vlad Sorta is employed as a Cadaster Counselor at the National Center for Cartography since 2018. His main task is the administration and monitoring of the Romanian Position Determination System – ROMPOS (https://www.rompos.ro/) and he is also involved in other projects, including the data processing and determination of a new gravimetric quasigeoid for Romania. He achieved the Ph.D. in Geodesy in 2013, and he was employed between 2007 and 2018 by the National Agency for Cadaster and Land Registration.

Neculai Avramiuc currently holds the position of Head of Geodesy and Research and Development Department, at the National Center for Cartography. He is the responsible for the project “Determination of a New Gravimetric Quasigeoid for Romania”. He is also the author of the national official coordinate transformation software TransDatRo (https://cngcft.ro/index.php/ro/download/download/2-software/4-transdatro-v4-06) which is in a continuous development.

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