Development of new geodetic infrastructure in Republic of Moldova

V. Chiriac, L. Nistor-Lopatenco, V. Grama, A. Iacovlev,
Faculty of Cadastre Geodesy and Construction,
Technical University of Moldova, Bd. Stefan cel Mare 168, MD-2004, Chisinau, Republic of Moldova

R. Jager, P. Spohn, G. Younis
Karlsruhe University of Applied Science, Institut für Angewandte Forschung und Fakultät für Geomatik,
Hochschule Karlsruhe – Technik und Wirtschaft (HSKA), Moltketrasse 30, D-76133 Karlsruhe, Germany

Abstract. Starting from 1999 a new reference system MOLDREF99 based on the ITRF97 and ETRS89 was established in Moldova. The realization of MOLDREF99 is the national GPS Network with density about 1 point per 15 sq. km. However, this density is insufficient for many geodetic applications. In order to provide real time positioning services the decision to pass from GPS "passive" Network to GNSS "active" Network in 2010 was adopted by Land Relation and Cadastre Agency.

To provide real time position and navigation service on the territory of Moldova a new project of GNSS Permanent Network and MOLDPOS service was supported by Norwegian Government.

To generate and distribute height anomalies for real time normal height determination from GNSS measurements a 3-4 cm accuracy Height Reference Surface based on precise GNSS/leveling was calculated by Technical University of Moldova in cooperation with Karlsruhe University of Applied Science.

For future improvement of Height Reference Surface for territory of Republic of Moldova, a gravity quasigeoid model based on new gravity and vertical deflections measurements will be created.

A new geodetic infrastructure including transformation parameters database and GNSS Network monitoring will be used for large spectrum of applications (geodetic works, cadastral surveying, GIS, mapping, navigation, etc.) and will be the basis for support of scientific applications (landslide monitoring, environmental research, geohazard prediction, meteorology, etc.).

Keywords. Global Navigation Satellite System (GNSS), Height reference System (HRS), Moldavian Positioning System (MOLDPOS), gravity measurements, levelling, quasigeoid.

1 Introduction

In 1999 Government of Republic of Moldova adopted European Terrestrial Reference System 1989 (ETRS89) as a base for national geodetic reference system MOLDREF99. Introduction of new reference system generate necessity to transform a huge amount of geodetic data and their integration in national spatial databases. In order to ensure precise and homogenous transformations for whole country territory it is necessary to create a new geodetic infrastructure taking in account previous geodetic works: development of new geodetic network using GPS (Global Positioning System) technologies, reconstruction of levelling network and creation of national gravity network.

At the same time the acceleration of informational and communication technologies increase the necessity of precise positioning using Global Navigation Satellite Systems (GNSS).
Starting from 2006 two permanent stations were installed in Chisinau: IGEO continuously operating station included in EUREF Permanent Network (EPN) and Technical University of Moldova permanent GNSS station CTIG-1. Stating from November 2011a GNSS permanent network for Moldavian Positioning System (MOLDPOS) will be operational (Fig. 1).

To put in commission MOLDPOS it is necessary to create databases for coordinate transformation and height conversion. Future development of real time MOLDPOS services includes communication architecture configuration, algorithms and data structure according RTCM (Radio Technical Commission for Maritime Services) standard. In the frame of research project "Development of a High Capacity Real-Time GNSS Positioning Service for Moldova (MOLDPOS)" (http://www.moldpos.eu) performed by Technical University of Moldova and University of Applied Science, Karlsruhe, Germany, a geodetic data bases were created for coordinate transformation from SC42 to MOLDREF99 and height conversion from GNSS ellipsoidal heights to normal Baltic Sea height system. Final geodetic data bases, software and communication system for RTCM messages were tested for trial zone.

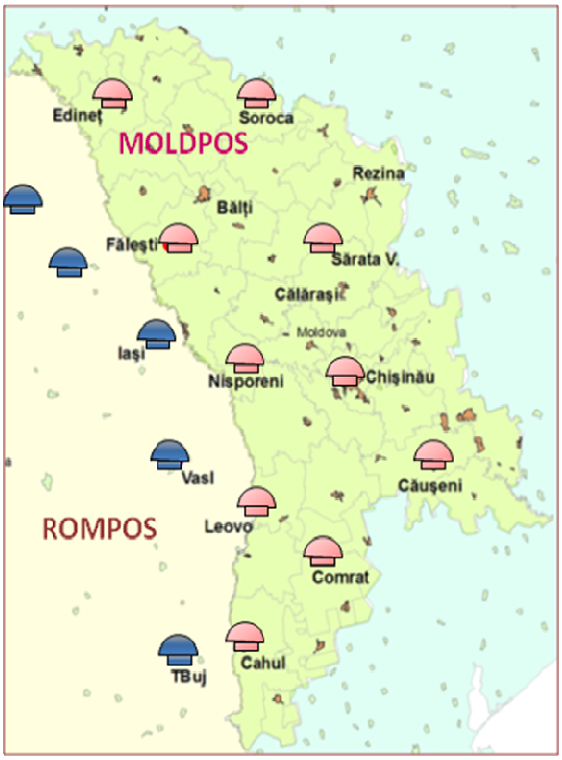

Fig. 1 GNSS permanent network for MOLDPOS services

To put in commission MOLDPOS it is necessary to create databases for coordinate transformation and height conversion. Future development of real time MOLDPOS services includes communication architecture configuration, algorithms and data structure according RTCM (Radio Technical Commission for Maritime Services) standard. In the frame of research project "Development of a High Capacity Real-Time GNSS Positioning Service for Moldova (MOLDPOS)" (http://www.moldpos.eu) performed by Technical University of Moldova and University of Applied Science, Karlsruhe, Germany, a geodetic data bases were created for coordinate transformation from SC42 to MOLDREF99 and height conversion from GNSS ellipsoidal heights to normal Baltic Sea height system. Final geodetic data bases, software and communication system for RTCM messages were tested for trial zone.

As a consequence of the executed research a new geodetic infrastructure will be developed and integrated in National Spatial Data Infrastructure and Infrastructure for Spatial Information in Europe (INSPIRE).

2 Geodetic databases development

2.1 Horizontal Datum Transformation

In case that the position (B,L,h) is related to a different datum and to another ellipsoid - meaning that the positions $(B,L,h)_1$ and $(B,L,h)_2$ belong to different reference ellipsoids (a_1,b_1) and (a_2,b_2) we have to take into account for the transition to $(B,L,h)_2$ the additional ellipsoid corrections ΔB, ΔL and Δh.

The final formulas for that general case the following observation equations for measured point positions $(B,L,h)_i$ in two reference frames:

$$\left(\begin{bmatrix} B \\ L \\ h \end{bmatrix}_2 - \begin{bmatrix} \Delta B_{(a,b)_1,(a,b)_2} \\ \Delta L_{(a,b)_1,(a,b)_2} \\ \Delta h_{(a,b)_1,(a,b)_2} \end{bmatrix} - \begin{bmatrix} B \\ L \\ h \end{bmatrix}_1 \right)_i + \begin{bmatrix} v_B \\ v_L \\ v_h \end{bmatrix}_i = R_{1i} \cdot \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \Delta s \\ t_x \\ t_y \\ t_z \end{bmatrix} \quad (1)$$

with

$$\begin{bmatrix} \Delta B_{(a,b)_1,(a,b)_2} \\ \Delta L_{(a,b)_1,(a,b)_2} \\ \Delta h_{(a,b)_1,(a,b)_2} \end{bmatrix} = \begin{bmatrix} B(a_2,b_2 \mid (X,Y,Z)_1) - B(a_1,b_1 \mid (X,Y,Z)_1) \\ 0 \\ h(a_2,b_2 \mid (X,Y,Z)_1) - h(a_1,b_1 \mid (X,Y,Z)_1 \end{bmatrix}$$

were R_{1i} is a Molodensky matrix for each control ground point with position B_i,L_i,h_i.

The advantage of the system of functional model (1) compared to well known similarity transformation in Cartesian geocentric coordinates (X,Y,Z) is, that observation equations (1) can simultaneously be used for complete 3D identical points (B,L,h), as well as for pure 2D identical horizontal points (B,L) and for pure 1D identical height points (h) in both systems.

Observation equations (1) have been implemented in the horizontal datum transformation software packages COPAG and WTRANS ((Jäger et al. (2006)).

The research project of the Technical University of Moldova in cooperation with Hochschule Karlsruhe - University of Applied Sciences (HSKA) aims at the parametric modelling and computation of transformation parameters for territory of Republic of Moldova from ccombined classical triangulation SC42 and ETRS89 control points from GNSS measurements (Fig 2).

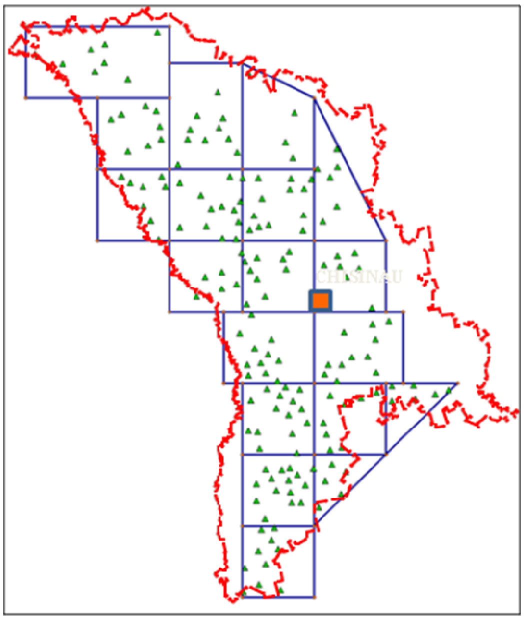

Fig.2. Meshes for ETRS89 and SC42 Datum-systems of Republic Moldova

The access to the transformation parameters model is enabled by COPAG (Continuously Patched Georeferencing) databases, which allow the transformations from SC42 datum to ETRS89 datum and inverse with 1 – 4 cm accuracy.

2.2 Height Reference Transformation

In case that the geodetic height *h* related to reference ellipsoid at position *(B,L)* is measured using GNSS receivers and normal height *H* from levelling related to quasigeoid surface is possible calculate Height Reference Surface (HRS) for specific area (Fig 3).

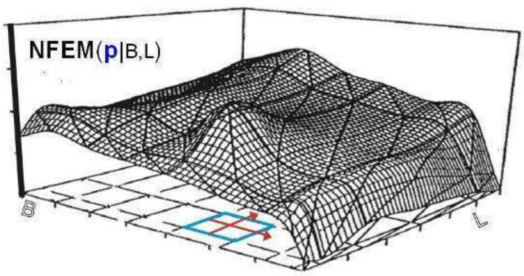

Fig. 3 Height reference surface representation as polynomial

In this work Height Reference Surface (HRS) is represented as polynomial using equation

$$\mathrm{NFEM}(\hat{\mathbf{p}} \mid \mathrm{B,L}) = \mathrm{f}^{\mathrm{T}} \cdot \hat{p}), \qquad (2)$$

with

$$\mathbf{f}(B,L) = [1 \mid B, L \mid B^2, B \cdot L, L^2 \mid \ldots]^T,$$

and

$$\hat{\mathbf{p}} = [\hat{p}_{00} \mid \hat{p}_{10}, \hat{p}_{01} \mid \hat{p}_{20}, \hat{p}_{11}, \hat{p}_{02} \mid \ldots]^T.$$

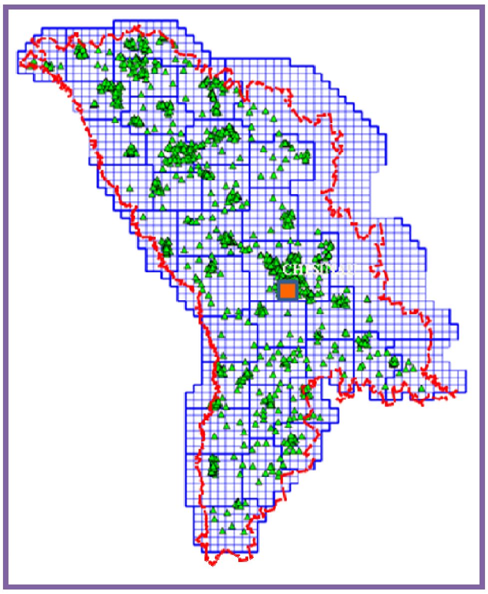

Fig. 4. GNSS/levelling measurements and meshes for HRS modelling

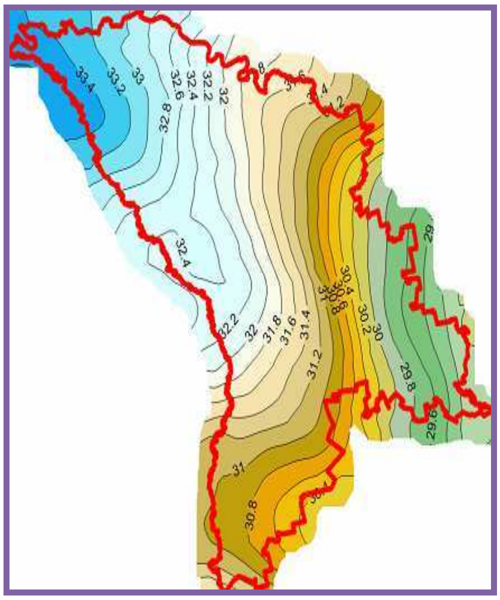

Fig.5. HRS model for territory of Republic of Moldova.

"Geometrical Part" of observation equations for GNSS-heights at position (B,L)

$$h + v = H + \text{NFEM}(\hat{\mathbf{p}} \mid B,L) = \hat{H} + \mathbf{f}(B,L)^T \cdot \hat{\mathbf{p}}, \tag{3}$$

Continuity equation along the mesh borders

$$C + v = C(\mathbf{p}) \tag{4}$$

For "Physical Part" of observation equations Global Geopotential model EIGEN-GL04C and European Gravity Geoid EGG97 were used.

Observation equation (2-4) have been implemented in the vertical datum transformation software packages DFEHRS (Digital Finite Element Height Reference Surface).

The research project of the Technical University of Moldova in cooperation with Hochschule Karlsruhe - University of Applied Sciences (HSKA) aims at the parametric modelling and computation of Height Reference Surfaces (HRS) for territory of Republic of Moldova (Fig. 4-6). The access to the parametric HRS model is enabled by DFHRS databases, which allow the direct conversion of GNSS-heights h into normal standard heights H.

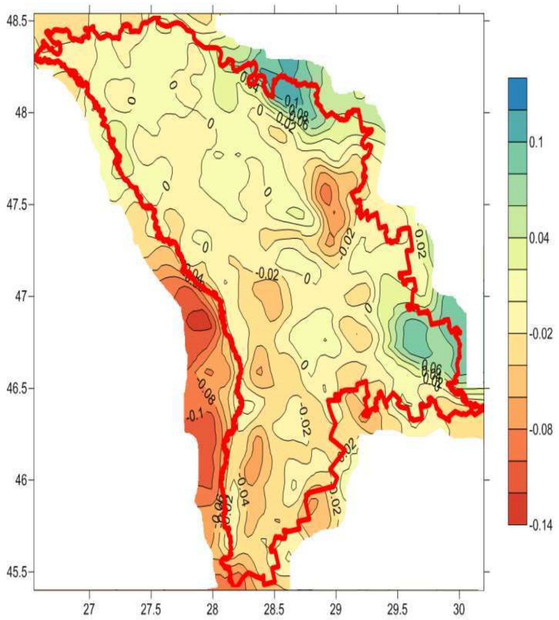

Fig.6. Model of obtained height residuals for territory of Republic of Moldova

3 Trials results

Geodetic databases were installed on Technical University of Moldova GNSS permanent station server for generation and transferring of RTCM messages to GNSS rover in the field via GPRS.

Trial GNSS measurements were conducted on second order levelling benchmarks which were not included in the model.

Table 1. Calculated normal heights of second order levelling benchmarks and heights differences

Second order levelling benchmarks	Levelling normal heights (m)	Calculated normal heights (m)	Heights difference (m)
Ratus	58.414	58.407	-0.007
Roman	128.279	128.256	-0.023
Ivancea	162.697	162.669	-0.028
Fed 160-1	73.082	73.094	0.012

The differences of normal height calculated from GNSS measurements and HRS model and levelling normal heights are not exceeding 3 cm for central part of the country (Table 1).

4 Conclusions

Development of real time Moldavian Positioning System MOPDPOS will allow to replace classical geodetic networks with GNSS permanent stations network based on ITRF (International Terrestrial Reference Frame).

COPAG databases could be used by MOLDPOS services for the transformations of SC42 datum to ETRS89 datum and inverse with 1 – 4 cm accuracy. DFHRS databases could be used by MOLDPOS services for direct conversion of GNSS-heights h into normal standard heights H and replacement of classical levelling by GNSS levelling.

As a consequence the research results can be used for MOLDPOS services extensions and data integration in National Spatial Data Infrastructure and Infrastructure for Spatial Information in Europe (INSPIRE).

COPAG and DFHRS databases can be used by a large spectrum of users (geodetic works, cadastral surveying, GIS applications, mapping etc.) and support of scientific applications (landslide monitoring, environmental research, geohazard prediction, geodynamic investigations etc.)

For future improvement of HRS model accuracy a gravity measurements for whole territory and vertical deviation along the state border to be included in calculations.

References

Jäger, R., Schneid, S., Kälber, S. and Seiler, S. (2006): Precise Transformation of Classical Networks to ITRF by CoPaG and Precise Vertical Reference Surface Representation by DFHRS – General Concepts and Realisation of Databases for GIS, GNSS and Navigation Applications. (Milan Talich, Ed.): Proceedings to the 1st International Fair of Geodesy, Cartography, Navigation and Geoinformatics. Prague, Czesk Republic. 16.03.2006 - 18.03.2006. ISBN 80-85881-25-X.

Jäger, R. and S. Kälber (2008): The New RTCM 3.1 Transformation Messages – Declaration, Generation from Reference Transformations and Implementation as a Server-Client-Concept for GNSS Services. Proceedings of GeoSiberia 2008 (22.04.2006 – 24.04.2006). Volume 1. S. 50-75. Novosibirsk, Russia. ISBN 978-5-87693-271-6.

Jäger, R. and R. Gyenes (2009): Deformation Integrity Monitoring for GNSS-positioning services inclduing a scalable hazard monitoring by the Karlsruhe approach (MONIKA). Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-Based and Ground-Based Augmentation Systems and Applications. Berlin, 11-14 November 2008. Berlin Senate Department for Urban Development. Berlin. ISBN 978-3-938373-99-6. p 106-107.

Jäger, R. and R. Kälber (2008): The New RTCM Transformation Messages. RTCM Paper No. 110-2008-SC104-508.

Jäger, R. and R. Gyenes (2009): Deformation Integrity Monitoring for GNSS-positioning services inclduing a scalable hazard monitoring by the Karlsruhe approach (MONIKA). Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-Based and Ground-Based Augmentation Systems and Applications. Berlin, 11-14 November 2008. Berlin Senate Department for Urban Development. Berlin. ISBN 978-3-938373-99-6. p 106-107.

Jäger, R. and R. Kälber (2008): The New RTCM Transformation Messages. RTCM Paper No. 110-2008-SC104-508,

Chiriac, V. (2006). National Report of Republic of Moldova. Proceeding of EUREF Symposium, Riga.

Chiriac, V. (2002). Establishing of Geodetic Reference Frame in the Republic of Moldova. Materials of the Geospatial Symposium, Prague, 9 p.

Chiriac, V. (2003) Determinarea anomaliilor altitudinilor pentru teritoriul Republicii Moldova. Materialele Conferinţei ştiinţifice privind crearea şi monitorizarea sistemelor de coordonate regionale utilizând tehnologiile moderne. Agenţia de Stat Resurse Funciare şi Cadastru. Chişinau, Iunie 2003, 5 p.

Chiriac, V. (2000). Determinarea înălţimii geoidului din măsurători gravimetrice prin metoda transformărilor Fourier. Rezumatele Conferinţei tehnico-ştiinţifice UTM, Chişinau, Mai 2000, v. 2, p. 168-172.

Chiriac, V. Pantikin, V. Krauterbluth, K.W. Ilies, I. Creţu, I. (2006). First Order Gravity Network of Republic of Moldova. Proceeding of the 1-st International Gravity Field Service “Gravity Field of the Earth”, Istanbul, September, 2006, ISNN 1300-5790, 420-423.

Chiriac, V. (2006). Continuously Operating Reference Station Network - A Future Strategy for Republic of Moldova. Proceeding of EUREF Symposium, Riga.