Technical University of Moldova

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Development of new geodetic infrastructure in Republic of Moldova

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Bundesministerium für Bildung und Forschung

EUREF 2011, Chisinau, 25-28 May, 2011

Subjects

- **Introduction**

Preconditions for new geodetic infrastructure development. Development of GNSS Permanent Network and MODPOS services

- **Geodetic databases development**

RTCM-based Positioning GNSS-Services. MOLDPOS architecture and communication configuration. Reference Datum Transformation. Height Reference Transformation. Testing out of geodetic databases

- **Generation of RTCM 3.1 Transformation messages**

Gridding for transformation messages. Structure of RTCM 3.1 messages

- **GNSS-Positioning Services Applications**

GNSS-Positioning Services – User-Groups. GNSS-based and Multisensor Low-Cost Platforms for Navigation and Object-Georeferencing. Growth of GNSS-Positioning Services User-Groups

- **Conclusions**

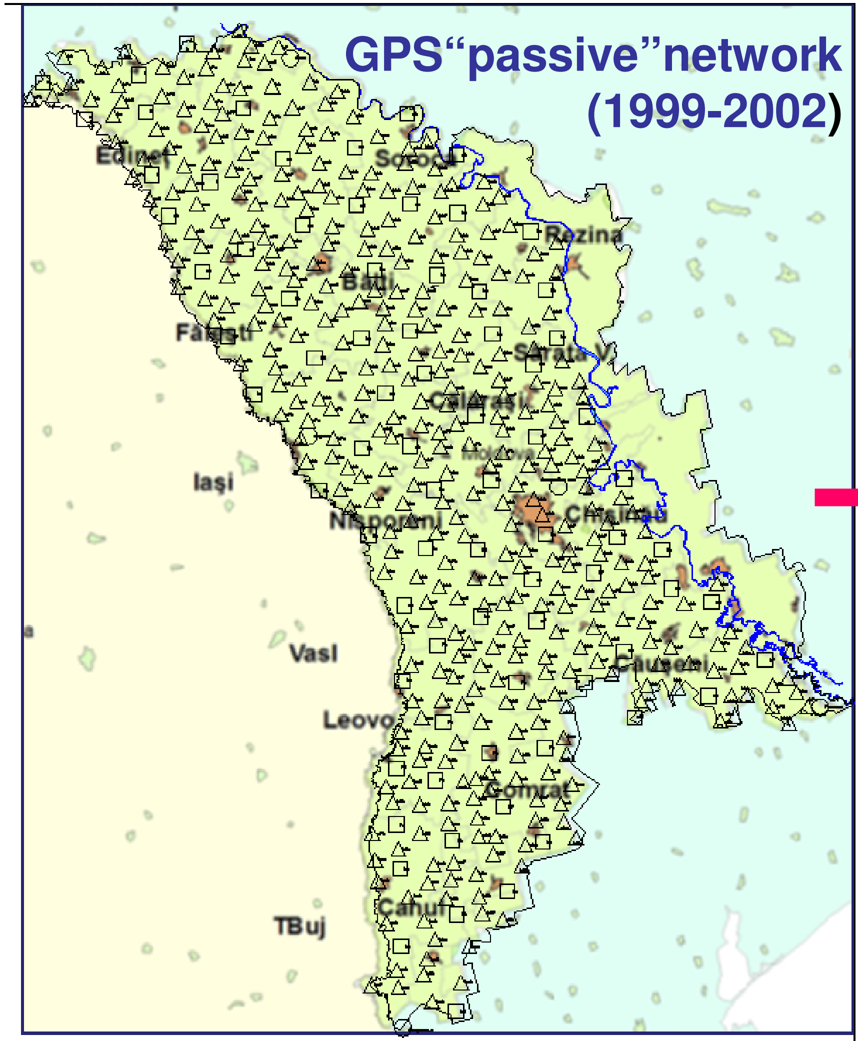
Introduction

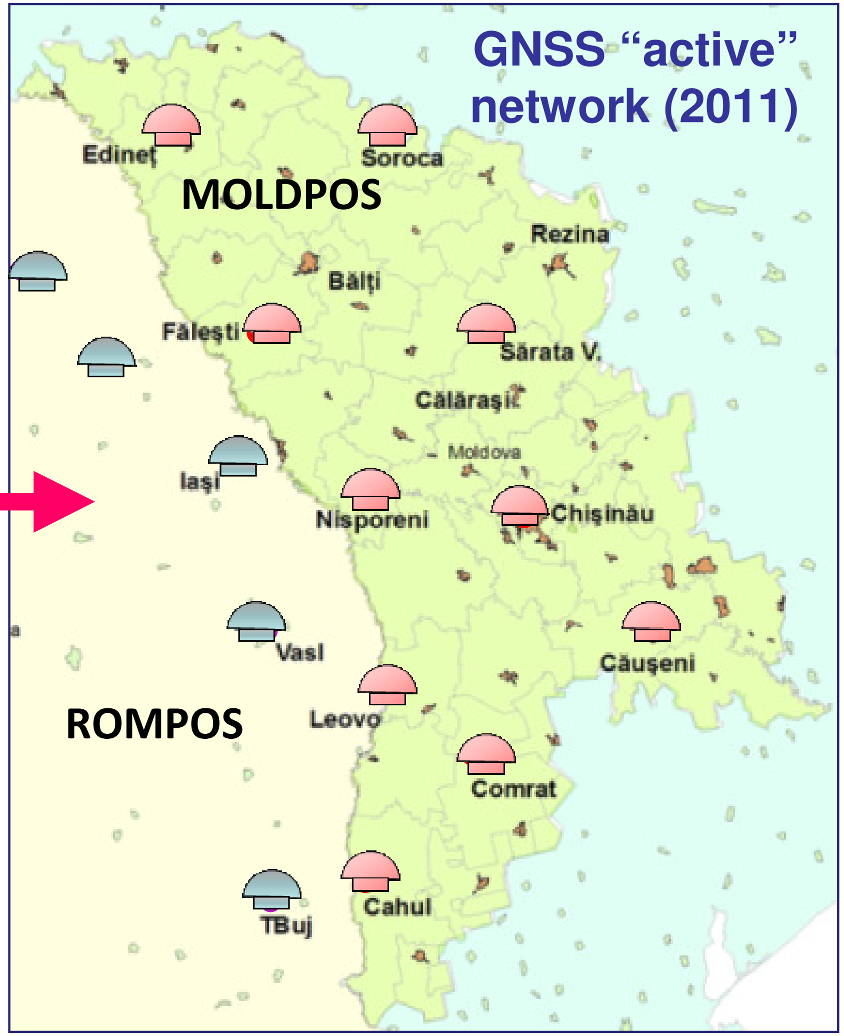
Preconditions for new geodetic infrastructure development

- **Development of new Moldavian Reference System MOLDREF99 and Transversal Mercator for Moldova (TMM) Map Projection (1999)**
- **Creation of the National Geodetic Network (1999-2002) and National Gravity Network (2006-)**
- **Reconstruction of National Leveling Network and future integration in ULEN (2002-)**
- **Installation of first permanent GNSS reference station at Technical University of Moldova in the frame of educational project JEP-24243-2003, TACIS-TEMPUS (2006)**
- **Installation and maintenance of IGEO (Chisinau) EPN permanent GNSS reference station by the Agency of Land Relations and Cadastre in collaboration with BKG (2007)**

Preconditions for new geodetic infrastructure development

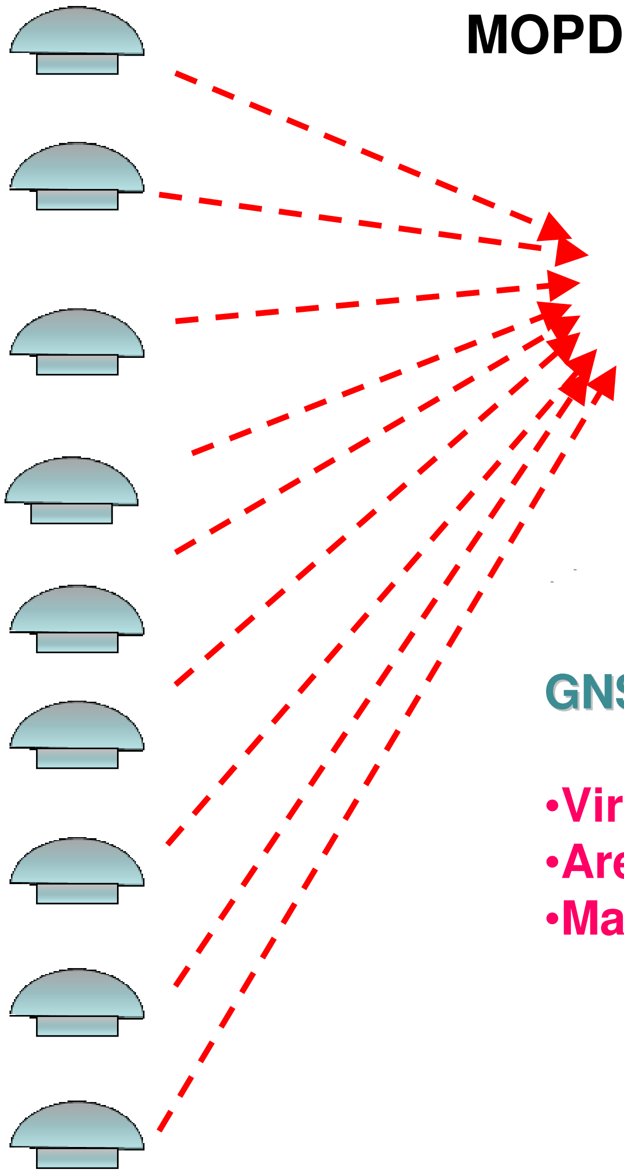
Development of GNSS Permanent Network and MOLDPOS service
(Government decision Nr. 307 from 28.04.2011)

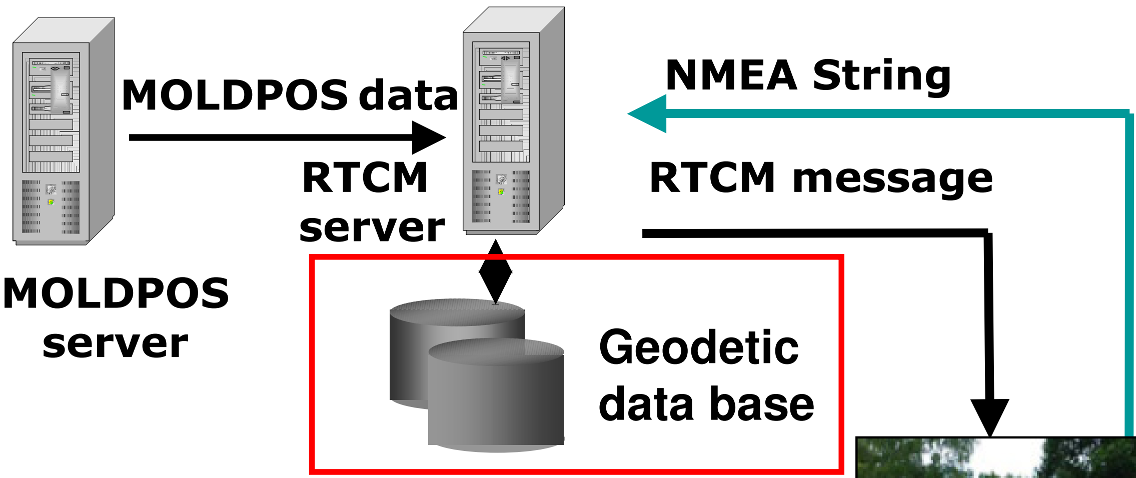




Geodetic databases development

MOPDPOS - RTCM-based Positioning GNSS-Services



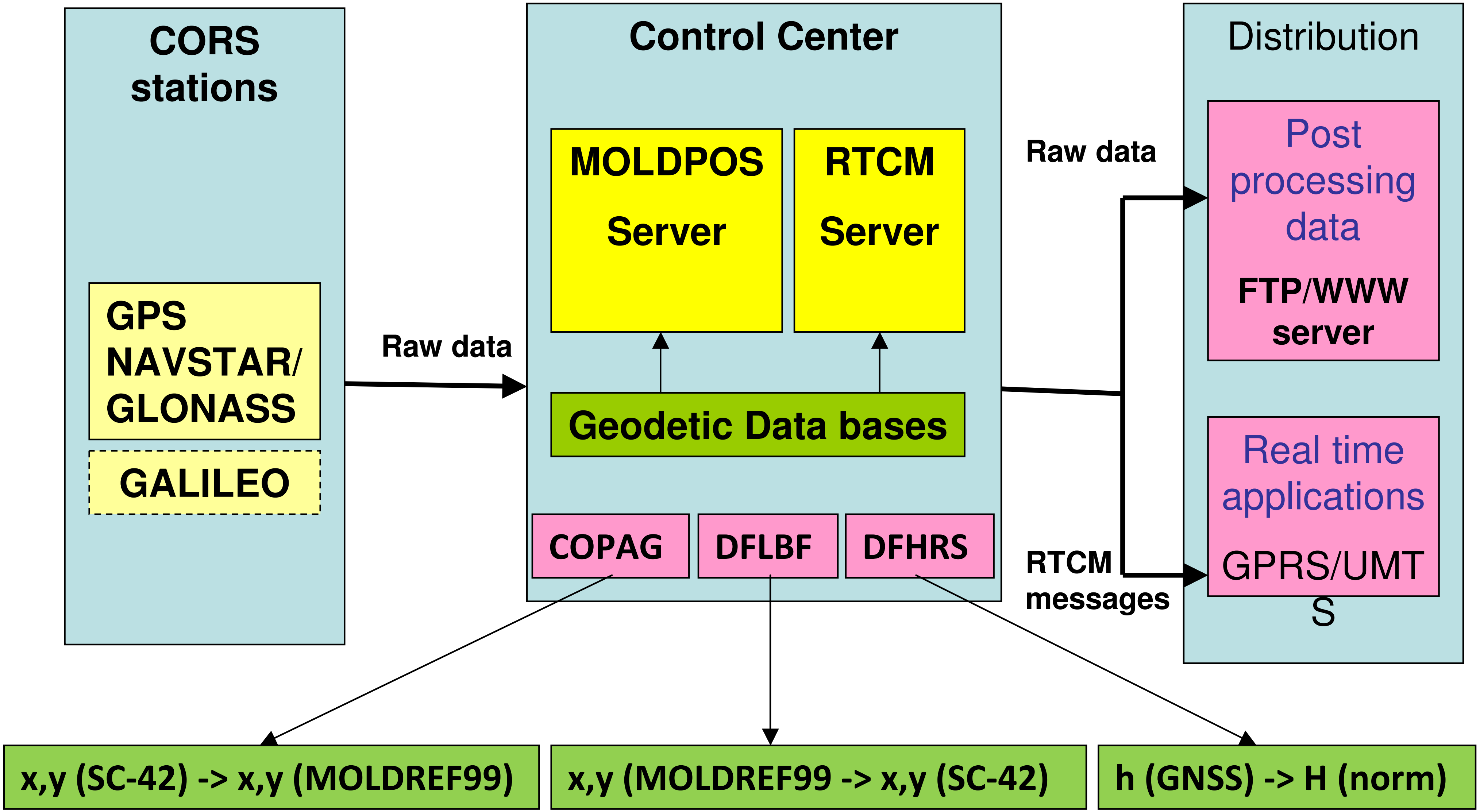


GNSS-Networking Concepts:

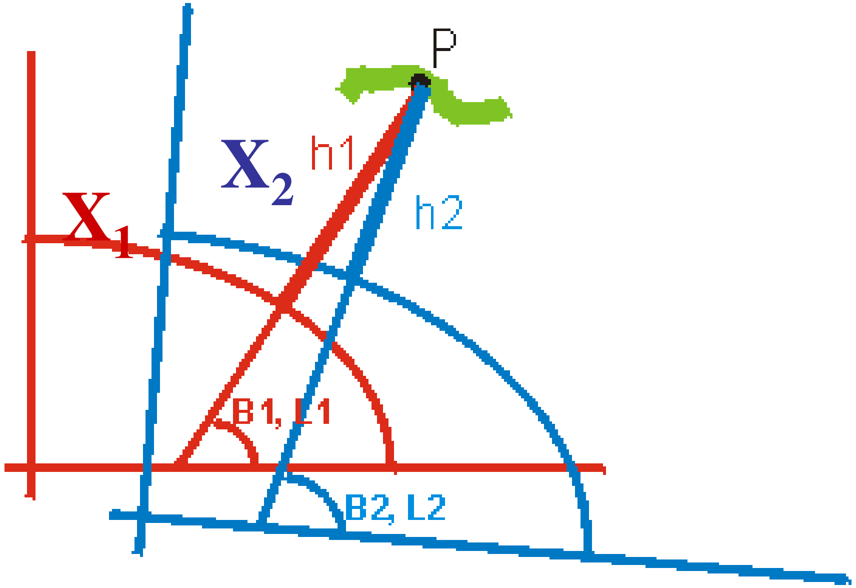
- Virtual Reference Station (VRS)
- Area Correction Parameters FKP
- Master-Auxiliary (MAX)

Geodetic databases development

MOLDPOS architecture and communication configuration



Reference Datum Transformation



$$X = (N+h)\cdot \cos B \cdot \cos L$$

$$Y = (N+h)\cdot \sin B \cdot \sin L$$

$$Z = (N - Ne^2 + h)\cdot \sin B$$

3D Transformation

$$\begin{bmatrix} X_2(B_2, L_2, h_2) \\ Y_2(B_2, L_2, h_2) \\ Z_2(B_2, L_2, h_2) \end{bmatrix} = s \cdot R \cdot \begin{bmatrix} X_1(B_1, L_1, h_1) \\ Y_1(B_1, L_1, h_1) \\ Z_1(B_1, L_1, h_1) \end{bmatrix} + t$$

Reference Datum Transformation

Karlsruhe Solution

Wtrans.lnk

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

1D-,2D-,3D-

Identical Points

WTRANS
www.geozilla.de

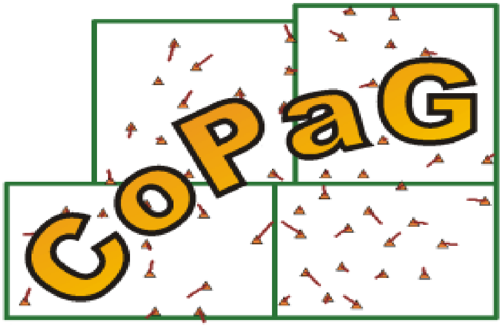
were ellipsoid transition corrections are:

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

$$\begin{bmatrix}
-\sin(L)\cdot\dfrac{a\cdot W+h}{M+h} & \cos(L)\cdot\dfrac{a\cdot W+h}{M+h} & 0 & \dfrac{-\sin(B)\cdot\cos(B)\cdot N\cdot e^2}{M+h} & \dfrac{-\sin(B)\cdot\cos(L)}{M+h} & \dfrac{-\sin(B)\cdot\sin(L)}{M+h} & \dfrac{\cos(B)}{M+h}\\
\dfrac{\sin(B)\cdot\cos(L)\cdot(N\cdot(1-e^2)+h)}{(N+h)\cdot\cos(B)} & \dfrac{\sin(B)\cdot\sin(L)\cdot(N\cdot(1-e^2)+h)}{(N+h)\cdot\cos(B)} & -1 & 0 & \dfrac{-\sin(L)}{(N+h)\cdot\cos(B)} & \dfrac{\cos(L)}{(N+h)\cdot\cos(B)} & 0\\
-N\cdot e^2\cdot\sin(B)\cdot\cos(B)\cdot\sin(L) & N\cdot e^2\cdot\sin(B)\cdot\cos(B)\cdot\cos(L) & 0 & h+a\cdot W & \cos(B)\cdot\cos(L) & \cos(B)\cdot\sin(L) & \sin(B)
\end{bmatrix}$$

Geodetic databases development

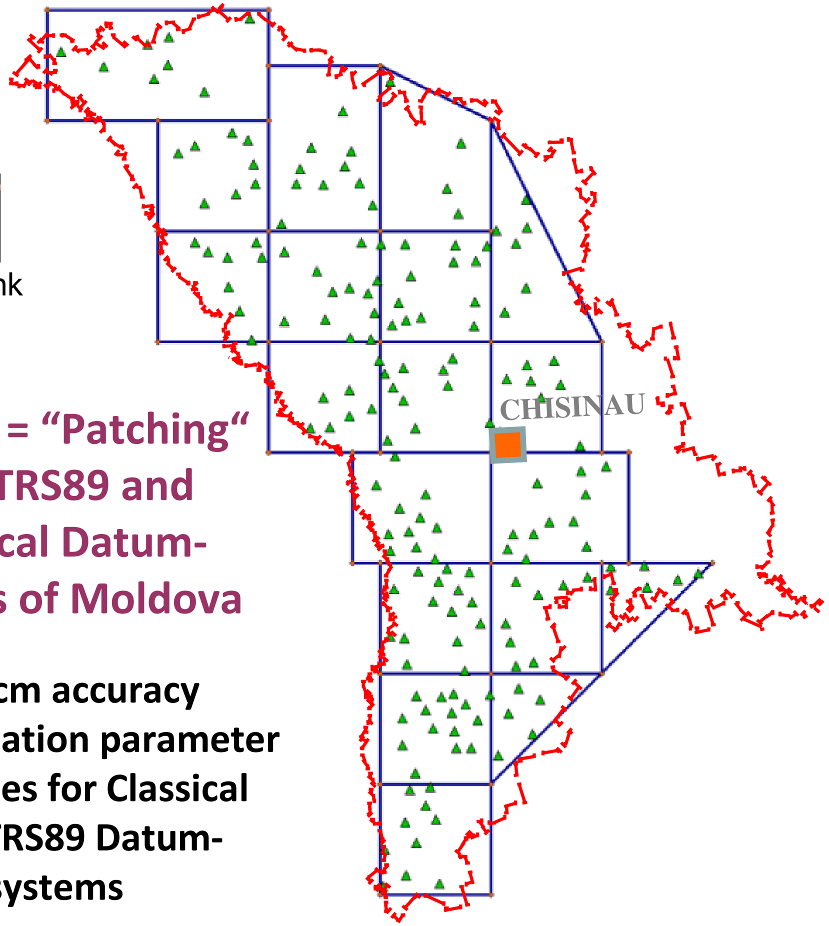
Reference Datum Transformation



COPAG =
<u>Co</u>ntinuously
<u>Pa</u>tched
<u>G</u>eoreferencing

Continuity along the Mesh Borders!

Copag.lnk



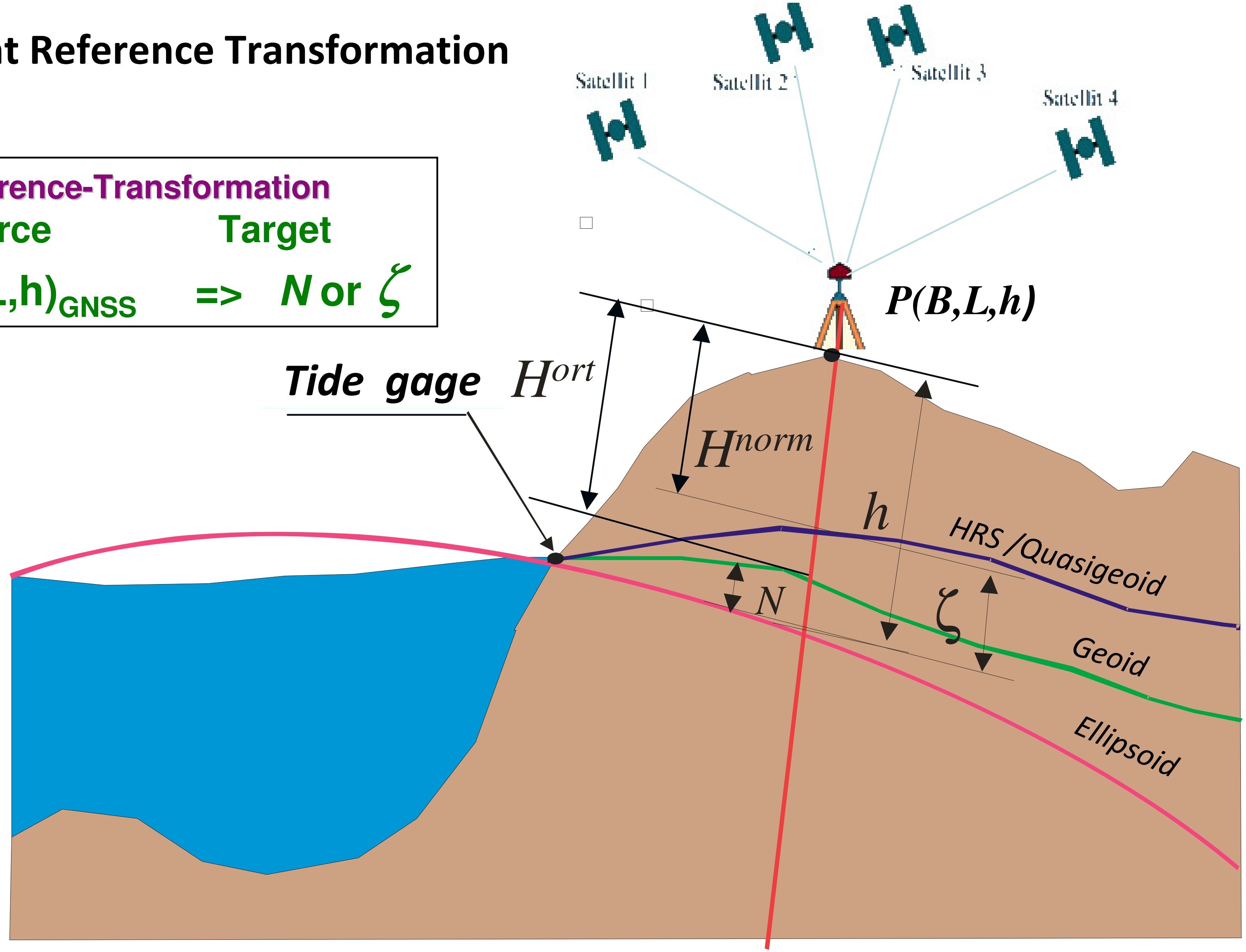
Meshes = "Patching" for ETRS89 and Classical Datum-systems of Moldova

1 – 4cm accuracy transformation parameter Databases for Classical and ETRS89 Datum-systems

Combined Old Classical Triangulation and ETRS89 Control Points from GNSS measurements

Height Reference Transformation

Reference-Transformation		
Source		Target
$(B,L,h)_{GNSS}$	=>	N or ζ



Geodetic databases development

Height Reference Transformation

GNSS-heights and levelling heights

$$\mathbf{h}_{GNSS} + v = H + \mathbf{f}^T \cdot \mathbf{p} - h_{GNSS}\Delta\, \mathbf{m}$$

Existing Geoid Grids or Grids from GPM

$$N_G{'}^{j} + v^{j} = \mathbf{f}^T \cdot \mathbf{p} + \partial N_G(\mathbf{d}^{j})$$

Vertical Deflection components

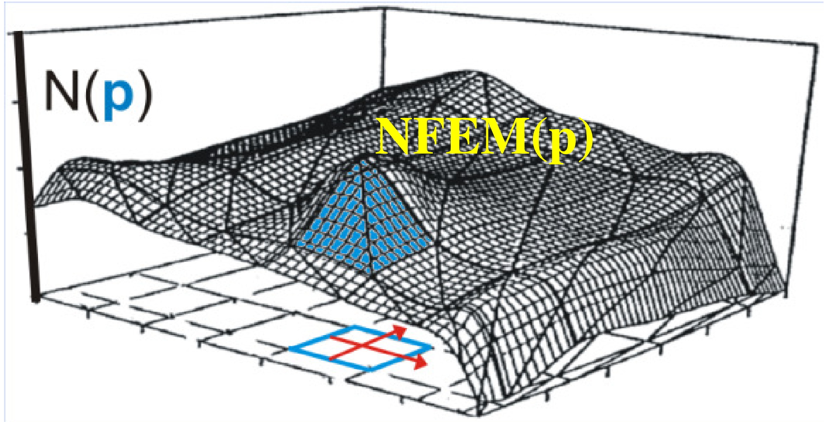
$$\xi^j + v = -\mathbf{f}_B^{\,T} / M(B) \cdot \mathbf{p} + \partial\, \xi\, (\mathbf{d}_{\xi,\eta})^{j}$$

$$\eta^j + v = -\mathbf{f}_L^{\,T} / (N(B) \cdot \cos(B)) \cdot \mathbf{p} + \partial\, \eta (\mathbf{d}_{\xi,\eta})^{j}$$

Continuity Equations along the mesh borders

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

Karlsruhe Solution for Digital Finite Element Height reference surface representation as polynomial



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

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

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

Observation Equations for the mapping of the coefficients of Global Geopotential Models (e.g. EGM2008, EIGEN)

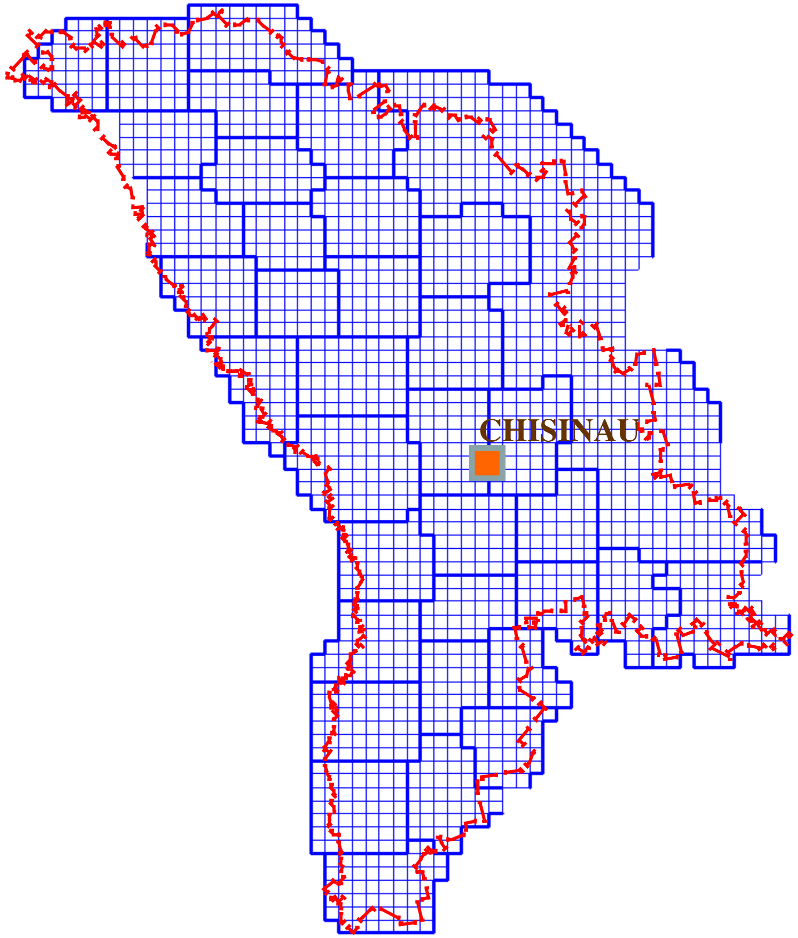
$$g_{grav} + v = \sum_{k=0}^{\infty} \left(\frac{a}{r}\right)^{n(k)+1} \frac{(n(k)+1)}{r} \sum_{m=0}^{k} (\bar{C}'_{n(k)),m} \cdot \cos m\lambda' + \bar{S}'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos\theta') \quad + dg(\mathbf{d})$$

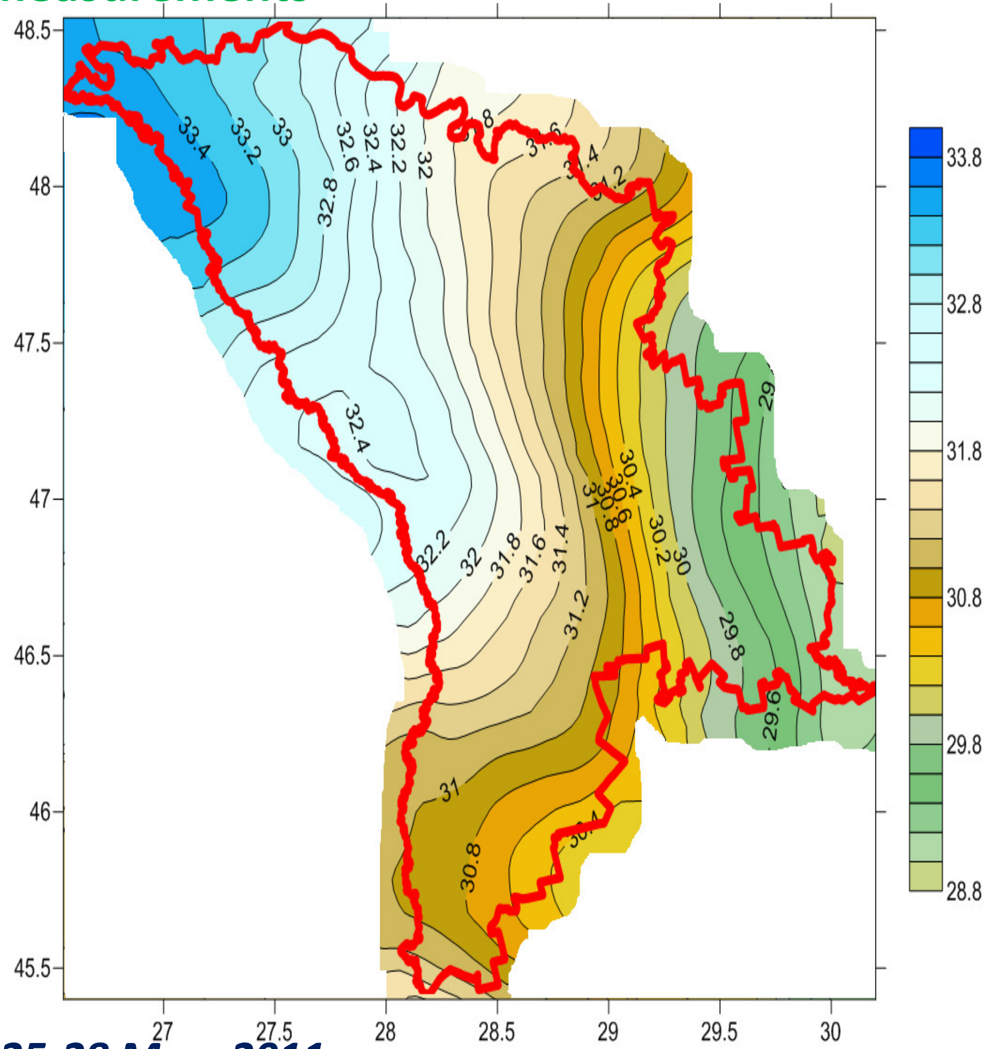
$$N_{GPM}^{j} + v = \frac{1}{\gamma_Q} (\sum_{k=0}^{\infty} \left(\frac{a}{r}\right)^{n(k)+1} \sum_{m=0}^{k} (\bar{C}'_{n(k),m} \cdot \cos m\lambda' + \bar{S}'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos\theta') - Vref) + \partial N(\mathbf{d}^{j})$$

Geodetic databases development

Testing out of geodetic databases

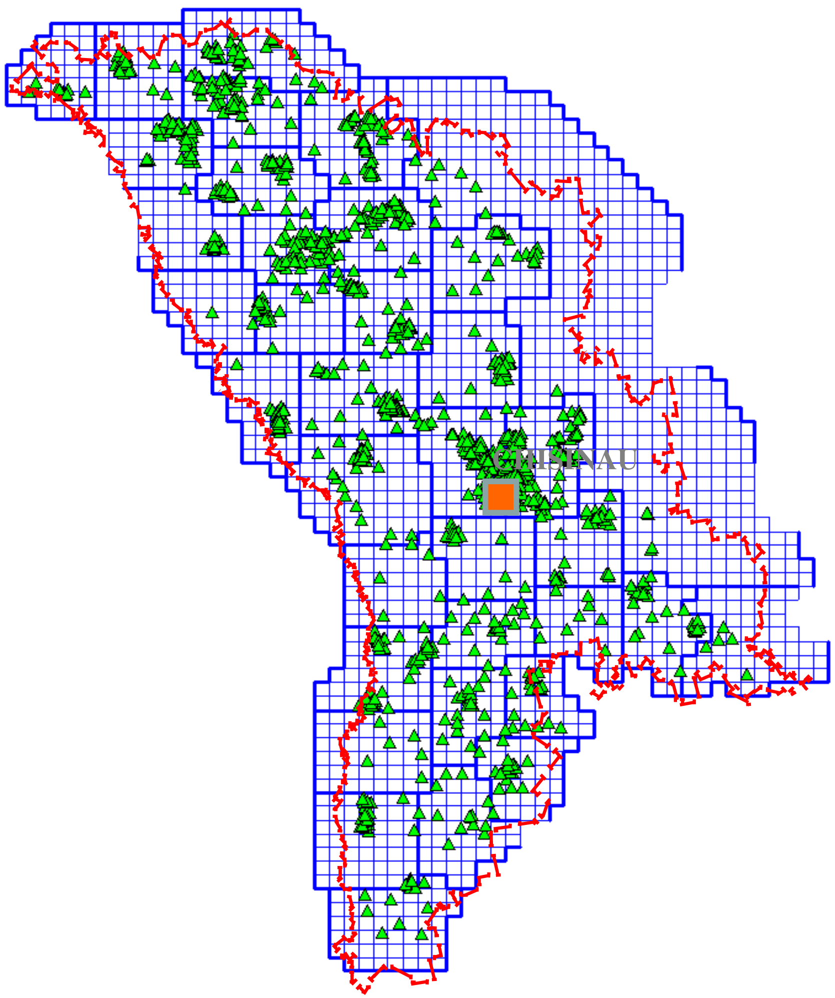
Modeling HRS/Quasigeoid for Moldova using EIGEN-GL04C EGG97 and GNSS/leveling measurements



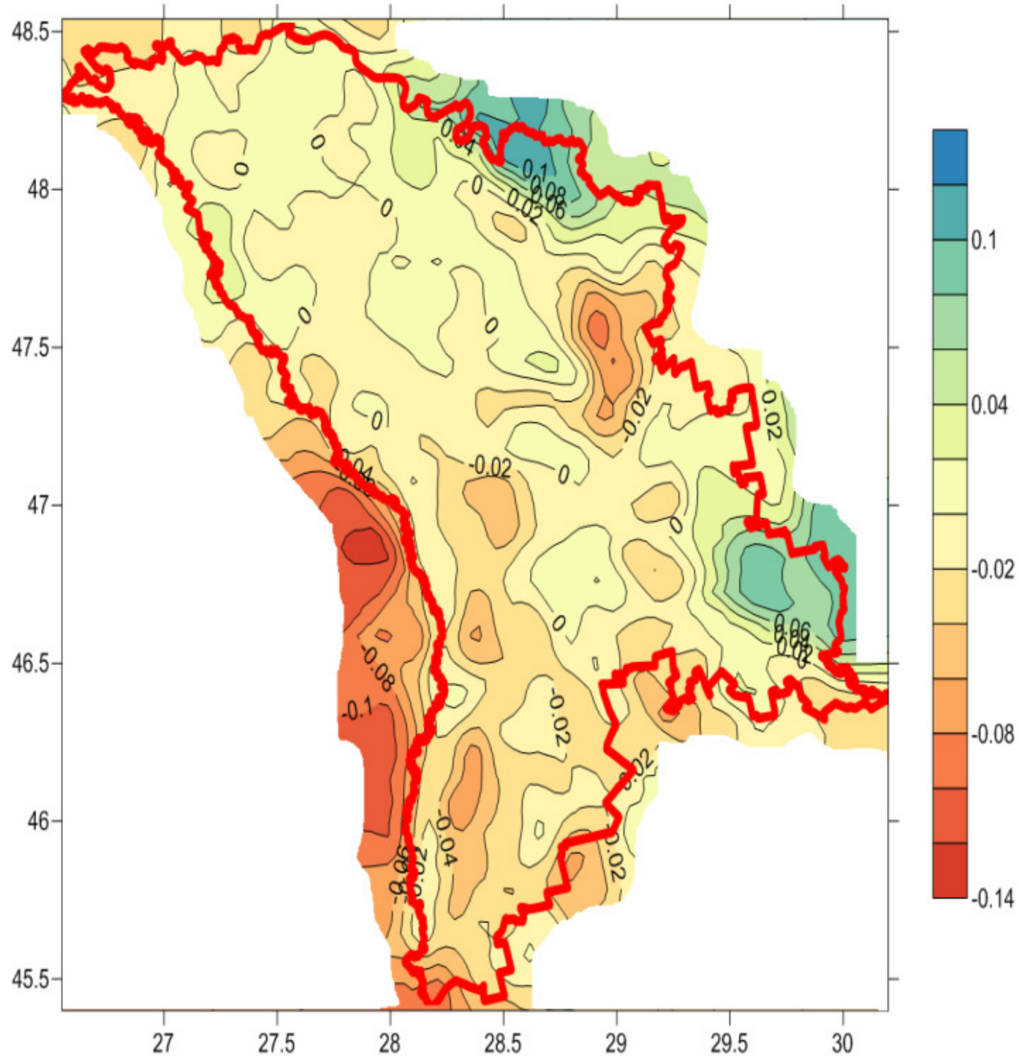


Geodetic databases development

Testing out of geodetic databases

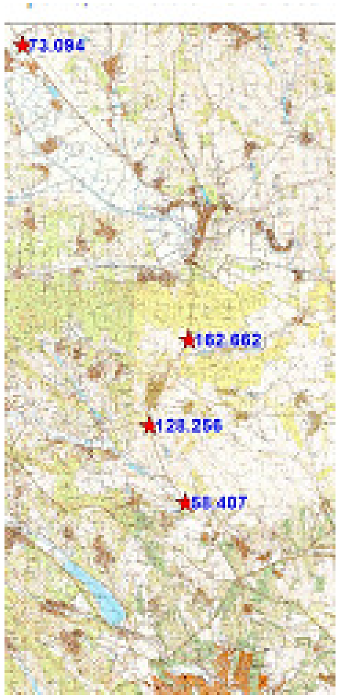


Accuracy of HRS/Quasigeoid for Moldova



Geodetic databases development

Testing out of geodetic databases

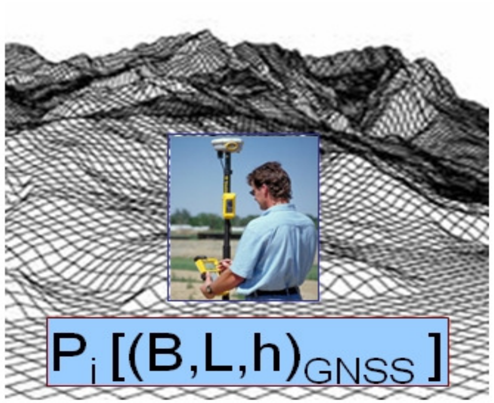


Second order leveling Benchmarks	MOLDREF99 Horizontal coordinates (m) X (N)	Y (E)	Leveling normal heights (m)	Calculated from GNSS measurements normal heights (m)	Heights difference (m)
Ratus	225920,222	230467.989	58,414	58,407	-0,007
Roman	232181,483	227567,418	128,279	128,256	-0,023
Ivancea 181010	239335,129	2306740,827	162,697	162,669	-0,028
Fed 160-1	263140,000	217246,770	73,082	73,094	0,012

Generation of RTCM 3.1 Transformation messages

Gridding for Transformation Message

Source CRS - Grid



Generated Grid of Local Virtual Fitting Points P_i

Any kind of individual

Reference Transformation

Target CRS - Grid

$P_i\,[(B,L)_{Class}]$

$P_i\,[(B,L,H)_{Class}]$

$P_i\,[N]$ $P_i\,[H=h_{GNSS} - N]$

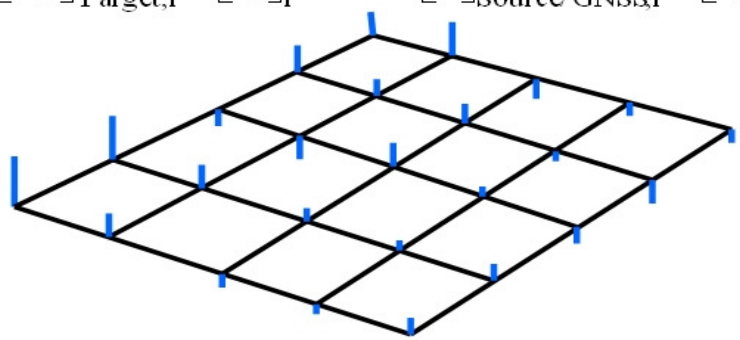
Resulting Local Virtual Fitting Points P_i

Gridding into 1.] and/or 2.]

1.] 7 Parameter Transformation

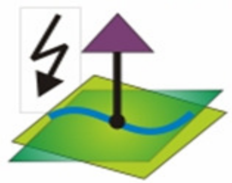
$$\begin{bmatrix} x_T \\ y_T \\ z_T \end{bmatrix}_{Target,i} + \begin{bmatrix} r_x \\ r_y \\ r_z \end{bmatrix}_i = s \cdot \mathbf{R} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{Source/GNSS,i} + \begin{bmatrix} t_x \\ t_x \\ t_z \end{bmatrix}$$

2.] Geoid/HRS Grid



7 Parameter Trend and 3D „Small“ Residual Grid

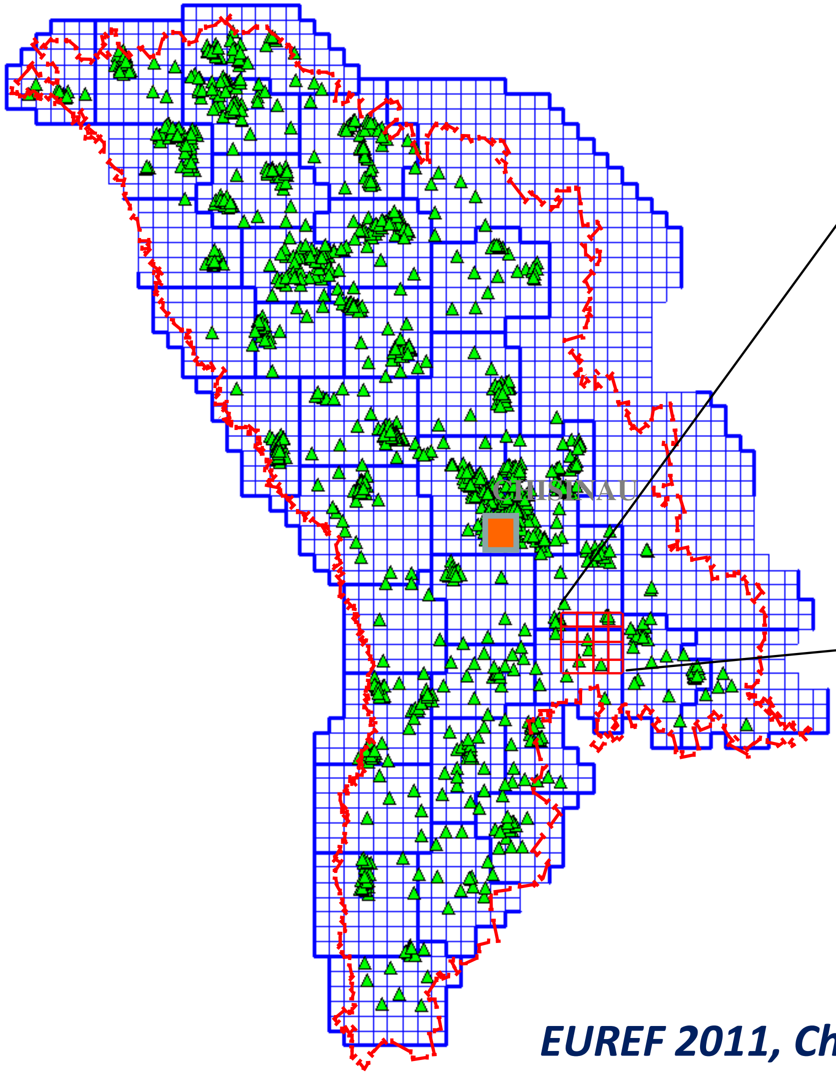
RTCM

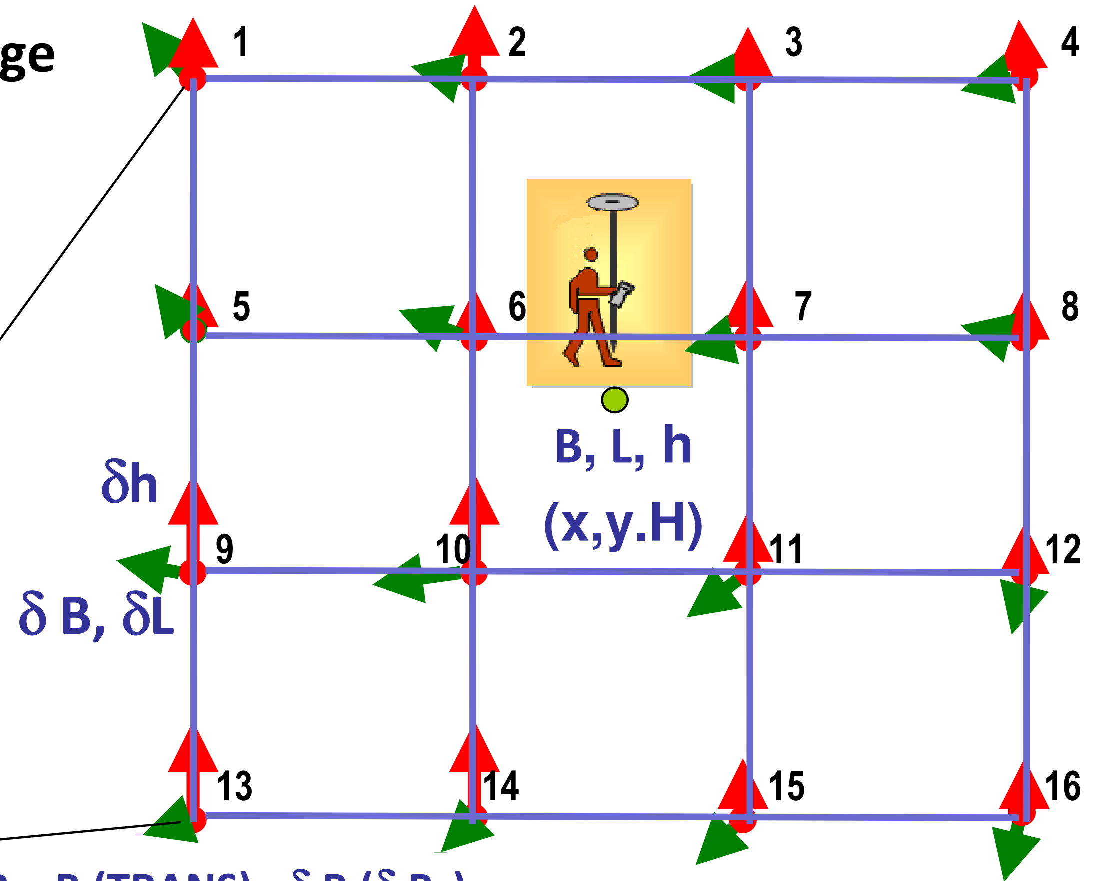


Grid of N_i

Generation of RTCM 3.1 Transformation messages

Gridding for Transformation Message





$B = B\,(TRANS) - \delta B\,(\delta B_i)$

$L = L\,(TRANS) - \delta L(\delta L_i)$

$h = h\,(TRANS) - \delta h\,(\delta h_i)$

(1) B, L, h => x, y, H

(2) B, L=> x, y

(3) H

Generation of RTCM Transformation messages

Structure of RTCM messages 1021 /1022

Data FIELD	DF NUMBER	Values	Remarks
Message Number	DF002	1021	
Source-Name Counter	DF+1	4	
Source-Name	DF+2	4258	ETRS89, Europa
Target-Name Counter	DF+3	7	
Target-Name	DF+4	31467	DHDN, GK-3
System identification number	DF+5	1	
Involved Transformation message	DF+6	0000000110	
Plate number	DF+7	7	
Computation Indicator	DF+8	1	
Height Indicator	DF+9	2	
ϕ_V	DF+10	49.0102	
λ_V	DF+11	8.3921	
$\Delta\phi_V$	DF+12	0.04	
$\Delta\lambda_V$	DF+13	0.06	
dX	DF+14	-617.880	
dY	DF+15	-253.456	
dZ	DF+16	-315.690	
R_1	DF+17	5.79748	
R_2	DF+18	-2.44443	
R_3	DF+19	-5.1534	
dS	DF+20	-13.51806	
add a_s	DF+24	8137.000	GRS80
add b_s	DF+25	6752.314	
add a_T	DF+26	7397.155	Bessel
add b_T	DF+27	6078.963	
Horizontal 7P Quality Indicator	DF+76	2	

Geoid-Grid or not

Grid Location&Size

7 Parameters

Ellipsoid Parameters Source / Target

Generation of RTCM Transformation messages

Structure of RTCM message 1023 /1024

::

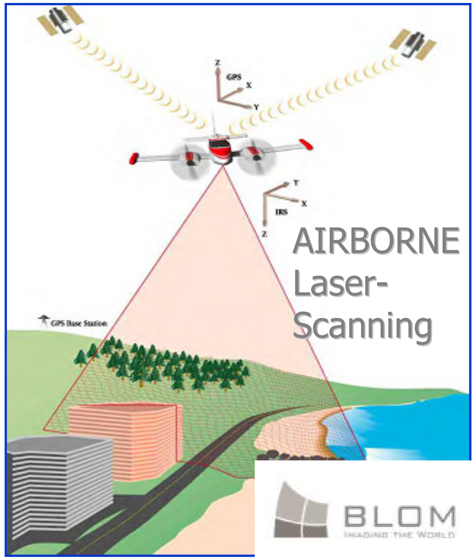
δN_{14}		DF+71	0.001	::
δE_{14}	Residuals P_{14}	DF+72	0.013	
δh_{14}		DF+73	0.049	
δN_{15}		DF+71	0.005	
δE_{15}	Residuals P_{15}	DF+72	0.009	
δh_{15}		DF+73	0.088	
δN_{16}		DF+71	0.006	
δE_{16}	Residuals P_{16}	DF+72	-0.002	
δh_{16}		DF+73	0.129	
Horizontal interpolation method indicator		DF+74	0	
Vertical interpolation method indicator		DF+75	0	
Horizontal Grid Quality Indicator		DF+78	1	
Vertical Grid Quality Indicator		DF+79	1	
Modified Julian Day (MJD) Number		DF+80	53570	

DFHRS Database use in direct access on controllers or for setting up the RTCM3.1 transformation-message, height indicator =2

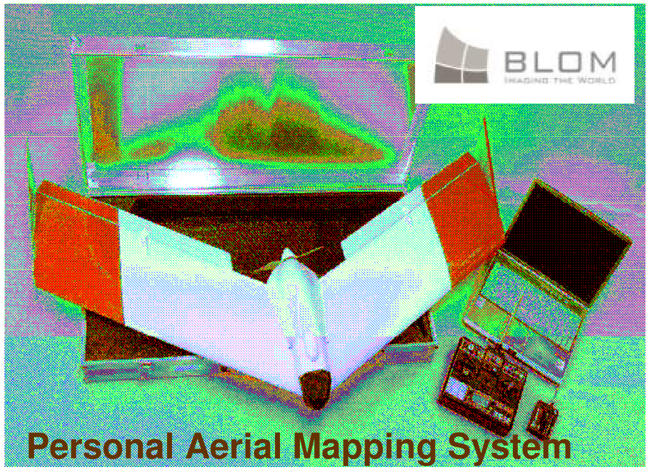
$$\boxed{H = h - \mathrm{NFEM}(\mathbf{p} \mid B, L)}$$

GNSS-Positioning Services Applications

GNSS-Positioning Services – User-Groups

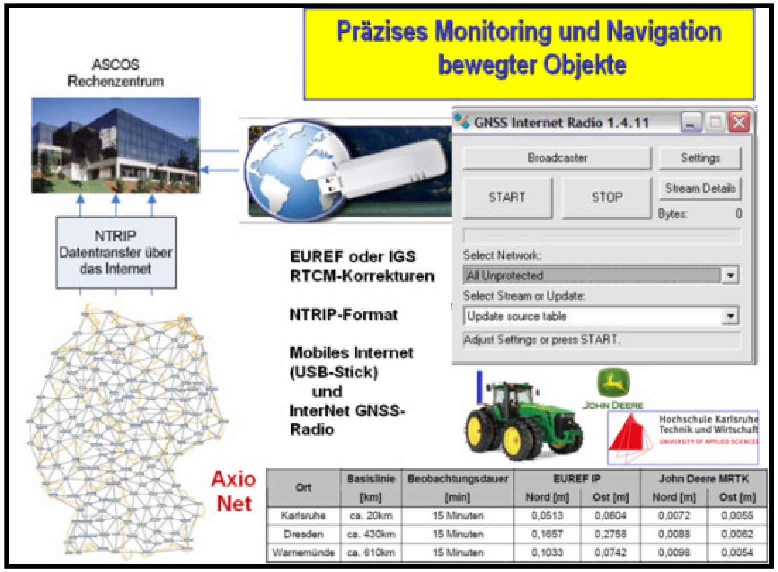


GNSS-based and Multisensor Low-Cost Platforms for Navigation and Object-Georeferencing



GNSS-Positioning Services Applications

Growth of GNSS-Positioning Services User-Groups



Ort	Basislinie [km]	Beobachtungsdauer [min]	EUREF IP Nord [m]	EUREF IP Ost [m]	John Deere MRTK Nord [m]	John Deere MRTK Ost [m]
Karlsruhe	ca. 20km	15 Minuten	0,0513	0,0604	0,0072	0,0055
Dresden	ca. 430km	15 Minuten	0,1657	0,2758	0,0088	0,0062
Warnemünde	ca. 610km	15 Minuten	0,1033	0,0742	0,0098	0,0054

Conclusions

- High precision Quasigeoid model will improve normal height determination from GNSS measurements using the MOLDPOS service
- Transformation Parameters data bases can be used by a large spectrum of users (geodetic works, cadastral surveying, GIS applications, mapping and boundary marking, etc.) and support of scientific applications (landslide and floods monitoring, environmental research, geohazard prediction, geodynamic investigations etc.)
- The new RTCM 3.1 transformation messages allows the GNSS service to provide their users with all necessary information for 2D positioning and GNSS-based height computation related to the national HRS
- For future improvement of Quasigeoid model accuracy a fitting GNSS/Leveling points related to 1st and 2nd order leveling networks, Gravity values of the national gravity network and vertical deflection measured by digital zenith camera along the state border to be included in the model

Thanks for attention

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Livia Nistor-Lopatenco
Vasile Grama
Andrei Iacovlev

Reiner Jager
Peter Spohn

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