ULAANBAATAR QGEOID COMPUTATION, PARAMETER ESTIMATION AND OPTIMIZATION CONCEPTS FOR GRAVITY FIELD DETERMINATION

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Introduction:

In the era of modern technologies and GNSS developments the precise quasi-geoid (QGeoid) model is necessary as geodetic infrastructure for GNSS services in different engineering needs, as it allows the determination of normal height much faster in comparison to levelling and directly from GNSS. This poster represents the software for QGeoid determination based on parametric modelling, as well as further version based on Adjusted Spherical Cap Harmonics (ASCH) modelling. The example of the QGeoid model for Ulaanbaatar region and computation results are introduced. The theory of deflections of vertical measurements by digital zenith camera is also included.

Computations of Ulaanbaatar qgeoid:

In order to compute the DFHRS_DB for Ulaanbaatar 94 Identical points (ellipsoidal h and normal heights H in Baltic Height system) together with the EGM2008 geopotential model data were used. EGM2008 is a spherical harmonic model of the earth's external gravitational potential in degree and order of 2160, with additional spherical harmonic coefficients extending up to degree of 2190 and order of 2160 that offers a spatial resolution of 9 km [1]. For meshing the area, mesh size of 5x5 km was chosen. Total amount of meshes – 1536. The total number of patches is 5. One patch must contain at least 4 fitting points.

Digital Zenith Camera [7]

Zenith camera and determination of DoV:

$$\mathbf{R}_{LGV}^{LAV} = \mathbf{R}_{LGV}^{LAV}(B,L,\eta,\xi) = \begin{pmatrix} \sin B\sin\Phi\cos(\Lambda-L)+\cos B\cos\Phi & \sin B\sin(\Lambda-L) & \cos B\sin\Phi-\sin\phi\cos\Phi\cos(\Lambda-L) \\ -\sin\Phi\sin(\Lambda-L) & \cos(\Lambda-L) & +\cos\Phi\sin(\Lambda-L) \\ \sin B\cos\Phi-\cos B\sin\Phi\cos(\Lambda-L) & -\cos B\sin(\Lambda-L) & \cos B\cos\Phi\cos(\Lambda-L)+\sin B\sin\Phi \end{pmatrix}^T$$

With the star coordinates at the observation time t_UTC have: $\mathbf{r}_{SI}^{LGV} = \mathbf{R}_{e}^{LGV}(B,L)\cdot\mathbf{r}^{e,s}\ (1)$

The general model for the vertical surface deflections determination the equation reads:

$$\mathbf{r}_{SI}^{LGV}(1) - \mathbf{r}_{SI}^{LGV}(2a,b) = \mathbf{0}$$

$$\mathbf{r}_{SI}^{LGV} = \mathbf{R}_{LGV}^{LAV}(B,L,\eta,\xi)^T\cdot\mathbf{R}_{b}^{LAV}(r=0,p=0,y)\cdot\mathbf{r}_{SI}^{b} = \mathbf{0}\ (2a)$$

$$\mathbf{R}_{b}^{LAV} = \begin{pmatrix} \cos p\cos y & \sin r\sin p\cos y-\cos r\sin y & \cos r\sin p\cos y+\sin r\sin y \\ \cos p\sin y & \sin r\sin p\sin y+\cos r\cos y & \cos r\sin p\sin y-\sin r\cos y \\ -\sin p & \sin r\cos p & \cos r\cos p \end{pmatrix}\ (2b)$$

Further development of the DFHRS software:

The extension of DFHRS concept and software to physical observation types – such as terrestrial, air- /space-borne gravity measurements or physical observation types taken from geopotential models, e.g. EGM 2008 – is based on a regional adjusted spherical cap harmonic parameterization (ASCH) of the Earth’s gravitational potential (V) [4,5]:

$$V(r,\lambda',\theta') = \frac{GM}{R}\sum_{k=0}^{k\,max}\left(\frac{R}{r}\right)^{n(k)+1}\sum_{m=0}^{k}(C'_{nm}cosm\lambda+S'_{nm}sinm\lambda)\bar{P}_{n(k),m}(cos\theta')$$

By introducing the disturbance potential applied to the Bruns theorem and Molodenski’s theory, we obtain the observation equation for fitting-points converted to quasi-geoid heights N_{OG} and vertical deflections $(\xi,\eta)_p$ at measured at the earth surface by zenith camera at a point P reading [3], [5], [6]:

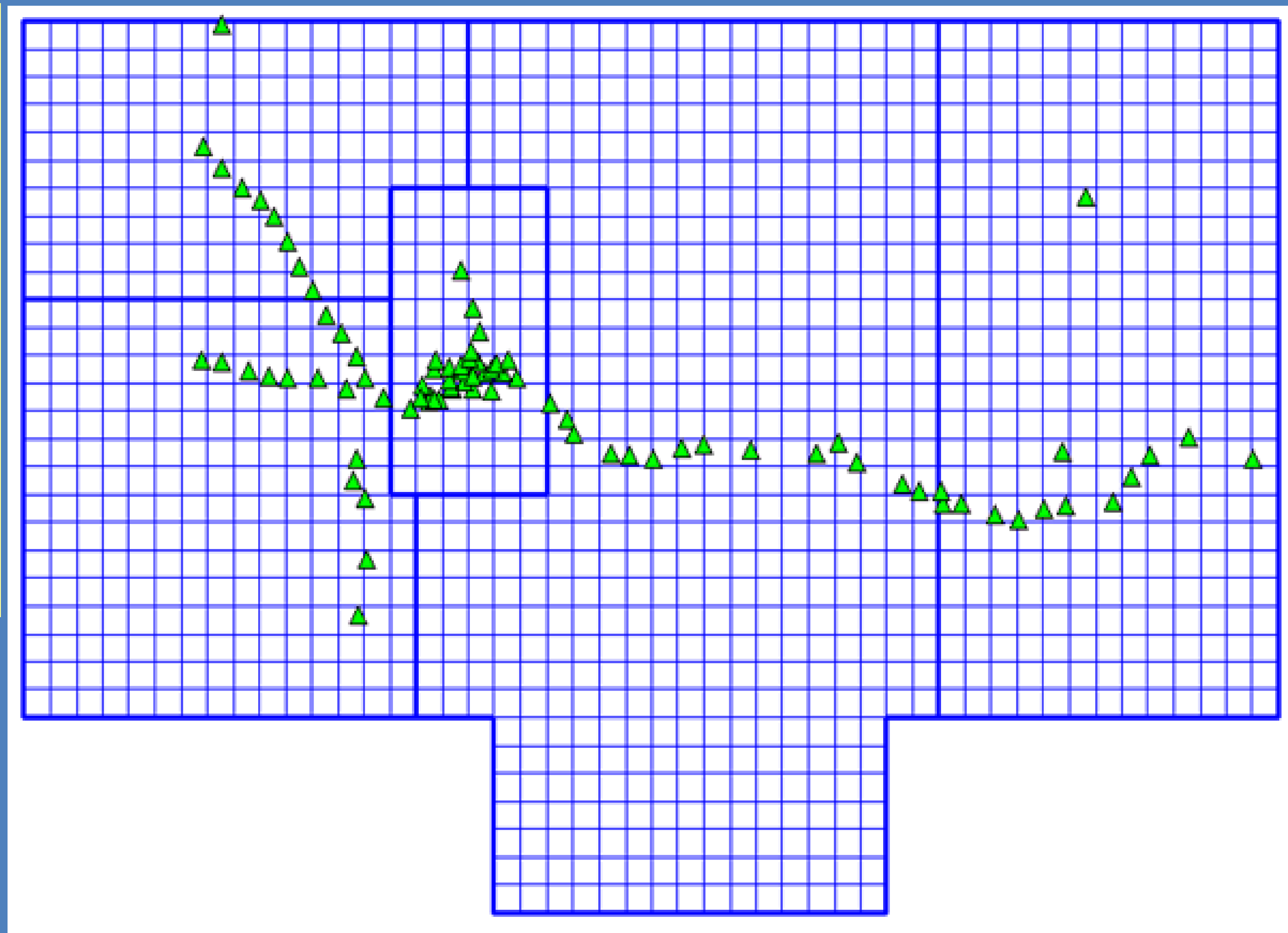
$$h - H = N_{QG} = \frac{T_p}{\gamma_Q}$$

$$\xi P = -\frac{\partial N_{QG}}{\partial s_N} = -\frac{\partial N_{QG}}{\partial B}\cdot\frac{\partial B}{\partial s_N} + dNCurv = -\frac{1}{\gamma_Q\cdot(M+h)}\cdot\left(\frac{\partial T}{\partial B}\right)_P + dNCurv$$

$$\eta P = -\frac{\partial N_{QG}}{\partial s_E} = -\frac{\partial N_{QG}}{\partial L}\cdot\frac{\partial L}{\partial s_E} = -\frac{1}{\gamma_Q}\left(\left(\frac{\partial T}{\partial L}\right)_P\right)\cdot\frac{\partial L}{\partial s_E} = \frac{-1}{\gamma_Q\cdot(N+h)\cdot cosB}\cdot\left(\frac{\partial T}{\partial L}\right)_P$$

$$\xi P = -\frac{1}{\gamma_Q\cdot(M+h)}\cdot\left[\left(\frac{\partial W}{\partial B}\right)_P - B\right)\Big]$$

$$\eta P = -\frac{1}{\gamma_Q\cdot(N+h)\cdot\cos B}\cdot\left[\left(\frac{\partial W}{\partial L}\right)_P - L\right)\Big]$$



Computation design of DFHRS (meshes – thin blue lines, patches – thick blue lines, fitting points – green triangles)

Computation results of Ulaanbaatar qgeoid:

The present DFHRS was calculated on the basis of the EGM2008 [2] geoid and 88 identical reference points. The accuracy of the identical points was confirmed with 1.0 cm, so the QGeoid of the Ulaanbaatar region has an estimated 1-3 cm accuracy within the area of the outer ring polygon-line of the fitting-points. The DFHRS_DB [3] can be used by the software DFHBF-Tools to compute the QGeoid-height N, and so the Normal Heights *H* from the input of a 3D GNSS-position *(B, L, h)* or *(X, Y, Z)*, and in order to set up a respective QGeoid 2018 grid for the Baltic Height System in the Ulaanbaatar Region.

Conclusions:

The quasi-geoid model for Ulaanbaatar region has been computed. The accuracy of the model is evaluated by 1-3 cm. As levelling data are not homogeneously provided in the region of interest, it would be necessary to use digital zenith camera [7] for vertical deflection determination for quasi-geoid improvement, as well as it allows additional check of normal heights. ASCH modelling in terms of integrated geodesy allow the combination of both geometrical and physical data, moreover this method is much faster in comparison to SH. Implementation of vertical deflections observations in terms of ASCH gives additional improvement of quasi-geoid and gravity field determination.

References:

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Acknowledgment: The research is funded by ESF Project: ESS2017/198/1.1.1.1/16/A/160.