APPLICATION OF THE GLOBAL GEOPOTENTIAL MODELS FOR DETERMINATION OF THE LEVELLING NORMAL CORRECTION

Stanisław Marganski (1), Katarzyna Kalinczuk-Stanałowska (2), Tomasz Olszak (1)

(1) Department of Geodesy and Geodetic Astronomy,
Warsaw University of Technology, Warsaw, Poland,
(2) Main Head of Geodesy and Cartography, Warsaw, Poland

ABSTRACT

Vertical networks in Poland are processed in the normal heights system called Kronstadt'86. Levelling evaluation of high precision measurements requires a determinations of normal levelling corrections, based on gravity Faye's anomalies. The purposes of the paper is to analyze the possibility of using in this computations the anomalies generated from global geopotential models while maintaining accuracy analysis which indicate a possible accuracy of Faye's anomalies. Authors have compared gravity anomalies obtained directly from measurements with gravity anomalies generated from different global geopotential models EGM96, GPM96, EGM2008. Authors have proposed an algorithm of gravity anomalies computation on geoid surface after free-air moving anomalies from geopotential models. Comparison was made on points of vertical networks located in medium-hill areas (around Starachowice near Kielce) and lowland (around Gostyn and Grudziadz) and on others test fields in Poland. The ability to use the geopotential models depends on their resolution. As a result of analysis concluded that only in the plain and lowland areas is possible to use data from global geopotential models with resolution above degree 720.

1. NORMAL CORRECTION

Polish levelling network is connected with normal height and Kronsztadt reference level. Every height difference measured between first and second orders levelling points should be reduced to normal height difference by add levelling normal correction:

$$P_N = -\frac{\gamma_0^B - \gamma_0^A}{\gamma_{śr}} H^n_{śr} + \frac{(g_0 - \gamma_0)_{śr}}{\gamma_{śr}} h_{AB}$$

where: - normal gravity values (obtained for Somigliana equation for GRS80 model); H - mean height od levelling section, h - measured height difference; (g0 - 0) - mean value of Faye's anomaly for one levelling section. First segment of normal correction is connected with normal gravity, the second considered measured difference between real and normal gravity - gravity anomaly. Such value should be obtained by gravimetric survey. But in Poland it was only interpolated form national gravimetric database.

2. PRELIMINARY ACCURACY ANALYSIS

The most important question at start point of this work was question - what error of gravity anomaly should be accepted and not significant if we want less error than 0,01mm in normal correction? Such analysis has done by Gauss law of error propagation.

$$m^2_{Ag_F^{śr}} = \frac{m^2_{P_N} - \left(\frac{\partial P_N}{\partial H^n_{śr}}\right)^2 \cdot m^2_{H^n_{śr}} - \left(\frac{\partial P_N}{\partial h_{AB}}\right)^2 \cdot m^2_{h_{AB}} - \left(\frac{\partial P_N}{\partial \gamma_0^A}\right)^2 \cdot m^2_{\gamma_0^A} - \left(\frac{\partial P_N}{\partial \gamma_0^B}\right)^2 \cdot m^2_{\gamma_0^B} - \left(\frac{\partial P_N}{\partial \gamma_{śr}}\right)^2 \cdot m^2_{\gamma_{śr}}}{\left(\frac{\partial P_N}{\partial Ag_F^{śr}}\right)^2}$$

Results of this step are:

- in first segment of normal correction contained normal gravity values, accuracy 0,1” in point position will be necessary to obtain normal gravity with precision guaranteed error not worse than 0,01 mm in normal correction,
- in second segment contained real gravity values, accuracy of gravity anomaly is depending on height difference (h).

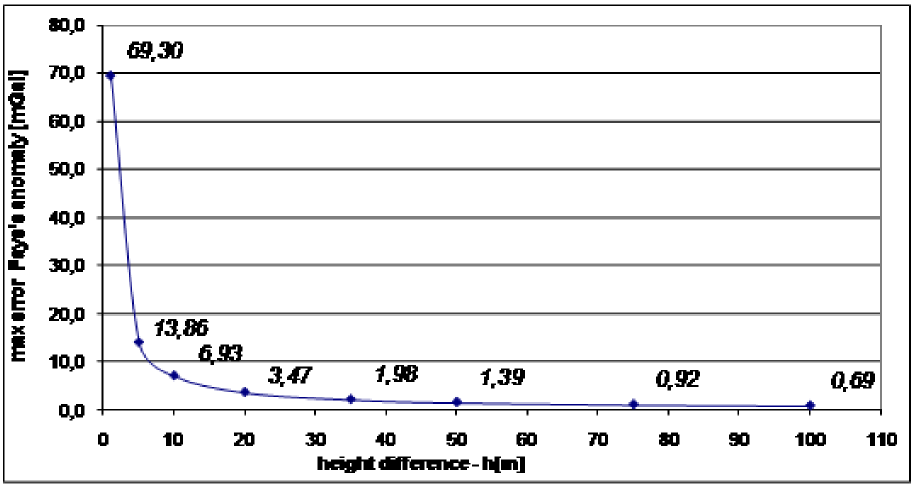

Fig. 1. Maximum error of Faye’s anomaly for different height differences on single levelling section.

As it is seen in fig. 1 for bigger height differences an error of gravity anomaly should be decreasing. Is clearly to see that accepted gravity anomaly error should be smaller for bigger height differences. Different parameters (such as precision of positions, error of height difference, mean section height and mean value of gravity anomaly for levelling benchmarks) are not significant.

3. ALGORITHM OF GRAVITY ANOMALY COMPUTATION

Gravity anomaly obtained from geopotential model isn’t connected with precise local geoid model. From other point of view local model is representing only by discrete grid of undulation. Simple algorithm was proposed “to move” gravity anomaly from geopotential model surface to precise local geoid. Gravity anomaly connected with local geoid model is defined by global model anomaly by:

$$Ag^{lok} = Ag^{glob} - 0{,}30855 \cdot \Delta N$$

“moving” function (dN) is understood as residual undulation between local and geopotential geoid. In case of models with small degree (360 or 720) this differences can have even ten metres. Residual undulation is defined by:

$$\Delta N = N^{glob} - N^{lok}$$

4. RESULTS

To compare results of gravity anomaly determinations several different datasets have been used. Mainly two sources of gravimetric data was prepared:
- almost 400 point of integrated national reference network, stations with precise ellipsoid coordinates, normal height and measured gravity values (max. error 20 mGals),
- every first order levelling benchmarks (near 16000 points) with knowing gravity anomalies computed by interpolation from national database.

In case of first set gravity anomalies was computed by Faye’s correction and compared with obtained from geopotential model. In the second case interpolated from national database gravity anomalies at levelling benchmarks and obtained from geopotential model were compared directly. Results of first way is presenting on figures 2, 3 and 4.

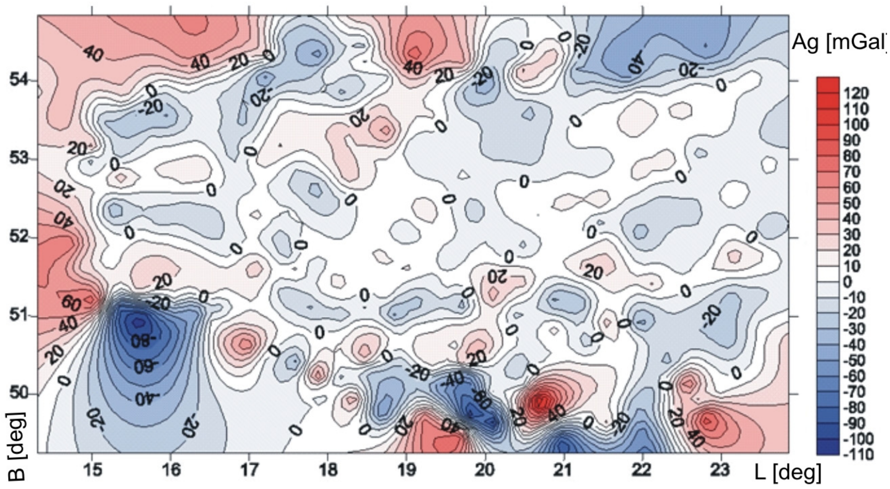

Fig. 2. Anomaly differences between reduced from terrestrial data and computed from EGM96 geopotential model [in miliGals].

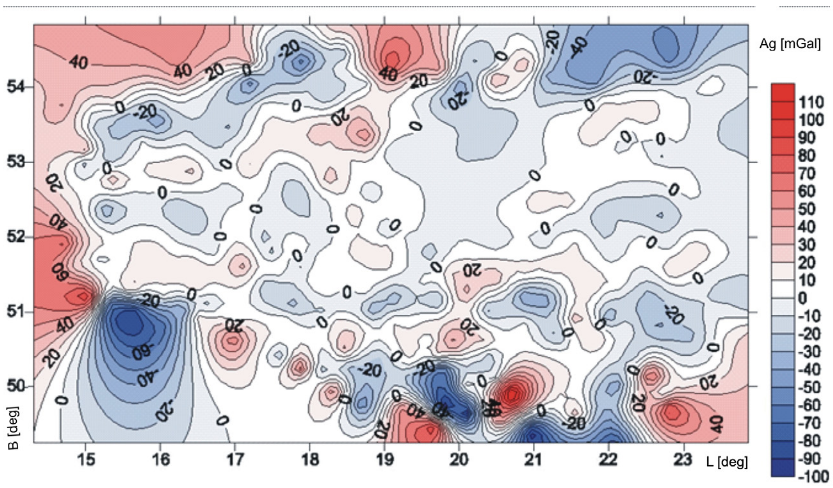

Fig. 3. Anomaly differences between reduced from terrestrial data and computed from GPM98 geopotential model.

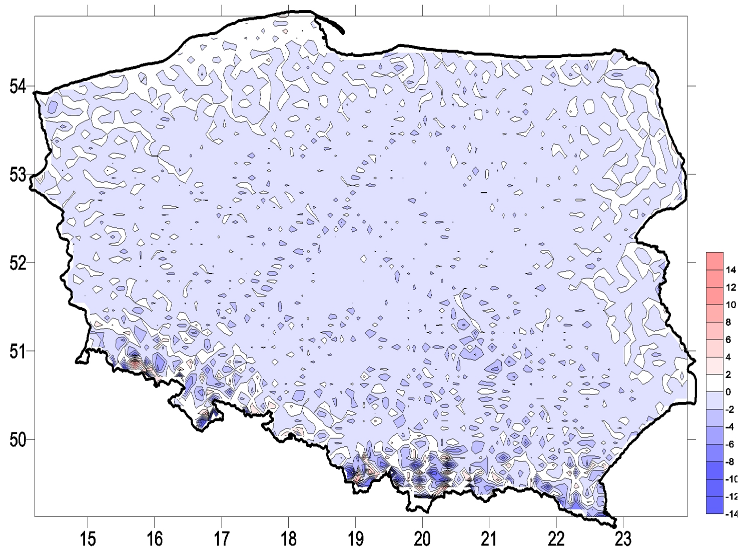

Fig. 4. Anomaly differences between reduced from terrestrial data and computed from EGM2008 geopotential model.

Conclusions after first solution are:
- obtained anomaly differences are strongly depend on degree of geopotential model,
- residuals are bigger in mountains areas, isn't good remark if we remember conclusion from initial accuracy analysis;
First results give possibility to use gravity anomaly computed from geopotential model only for flat and submontane areas.

As example of comparison between interpolated anomalies and computed from geopotential model levelling polygon near Starachowice was pointed out. Polygon consist 8 levelling lines and 400 benchmarks. It ocurres in submontane area in Świętokrzyskie Mts (see fig. 5) with significant height differences (up to 50 meters).

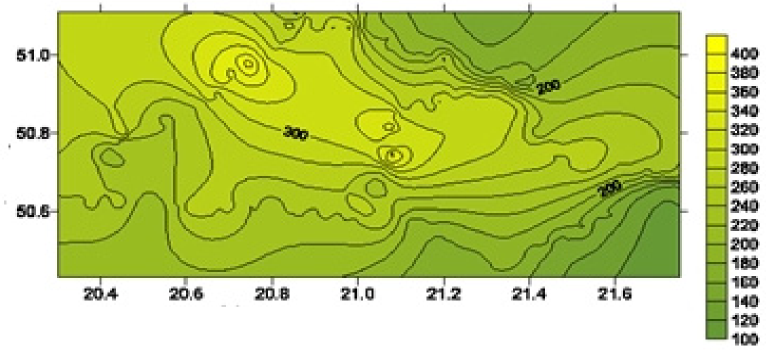

Fig. 5. Topography near Starachowice polygon.

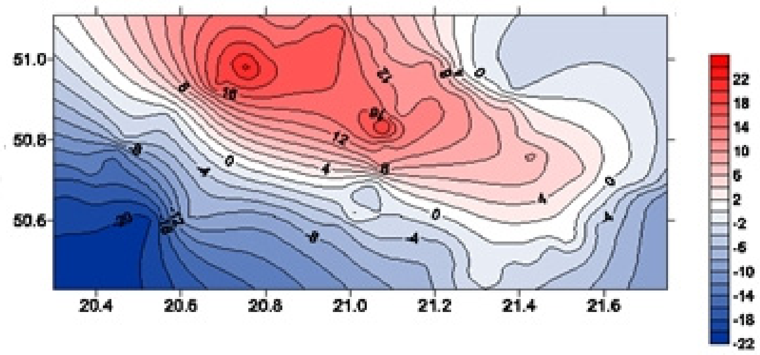

Fig. 6. Anomaly differences between interpolated and EGM96.

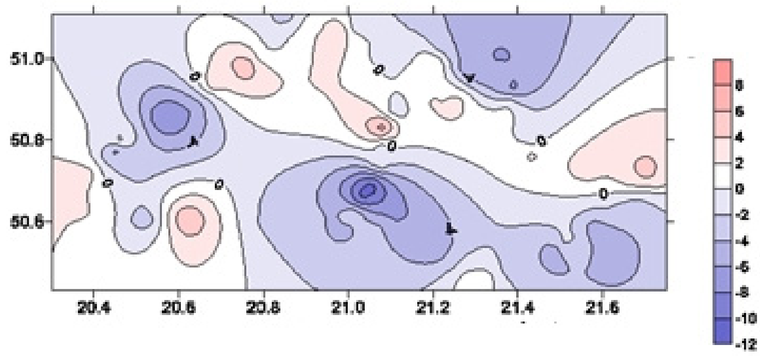

Fig. 7. Anomaly differences between interpolated and GPM98.

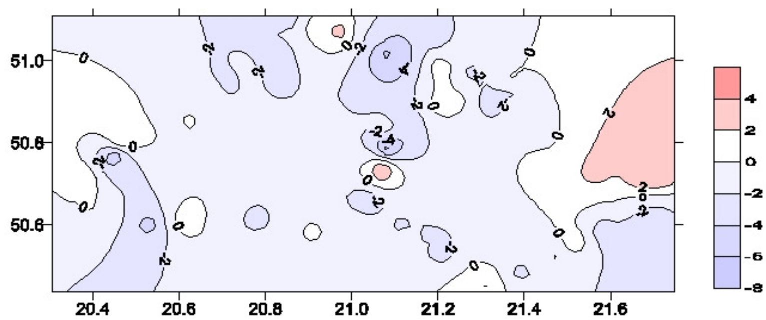

Fig. 8. Anomaly differences between interpolated and EGM2008.

Results confirmed conclusions typed before. The biggest residuals obtained for small degree model (EGM96). In case of GPM98 model maximum residual not exceed 8 mGals. For EGM2008 model such maximum residuals have decreasing to 4 mGals.
Proposed method guaranteed enough accuracy of gravity anomaly computation for normal correction for flat and small mountainous areas. In this cases EGM2008 model can be useful to compute gravity anomalies instead of survey or interpolate.

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