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Evaluation of the Performance of the New EGM2008 Global Geopotential Model over Poland

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Abstract. The performance of the new EGM2008 global geopotential model, over Poland, has been evaluated. The tide-free release of the EGM2008 model was also used for the assessment of quality of three precise quasigeoid models developed in the last decade in Poland. The EGM2008 model was compared with GPS/levelling as well as regional gravimetric quasigeoid models. The results obtained confirm high quality of quasigeoid models in Poland. They are in agreement with the previous estimate of their accuracy. Regional quasigeoid model calculated using the EGM2008 model has been found fully comparable with the existing precise quasigeoid models. EGM2008-based quasigeoid model was used to detect outlying GPS/levelling heights in the data set used for the assessment of quality of gravimetric quasigeoid models in Poland.

Keywords: global geopotential model, regional quasigeoid model, EGM2008

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1. Introduction

The activities in the domain of regional geoid modelling in Poland became extensive in the last two decades. The determination of the first gravimetric quasigeoid model for Poland developed using the least squares collocation combined with the integral method (Lyszkowicz, 1998; Krynski, 2007) was followed by the gravimetric quasigeoid model obtained using the FFT technique and substantially extended gravity data set (Lyszkowicz, 1996). This last model was fitted to GPS/levelling heights of the sites of the POLREF, EUVN, and eventually WSSG (Military Satellite Geodetic Network) networks in different ways providing different quasigeoid models (e.g. Lyszkowicz, 1998; Kadaj, 2001; Pażus et al., 2002). In both cases gravimetric quasigeoid models were developed with remove-compute-restore method using OSU86 (360, 360) and EGM96 (360, 360) global geopotential models, respectively.

An extensive research on modelling a precise quasigeoid in Poland was taken within the project conducted in 2002-2005, ordered and supported by the Polish Committee for Scientific Research (Krynski, 2005a). In the framework of the project numerous models of a quasigeoid in Poland were generated with the use of recently available geodetic, gravimetric, astronomic, geological and satellite data. Also the suitability of different global geopotential models for modelling precise quasigeoid in Poland was investigated (Krynski and Lyszkowicz, 2005a). Besides EGM96, the global geopotential models obtained from CHAMP and GRACE space gravity missions, i.e. EIGEN-CH03S, GGM01S, GGM02C, and GGM02S/EGM96 were considered. It has been shown that the best quasigeoid models are those determined with the use of EGM96 or GGM02S/EGM96. It was also shown that the replacement of EGM96 with GGM02S/EGM96 geopotential model, does not significantly contribute to the improvement of the fit of quasigeoid in Poland to GPS/levelling

Geoinformation Issues
Vol. 1, No 1, 7-17/2009

data. This indicates that the improvement in low frequency band of geopotential models in first satellite solutions based on GRACE data was not sensed in the process of modelling quasigeoid in Poland.

The accuracy of heights in the existing GPS/levelling networks, i.e. POLREF, EUVN, and WSSG was found insufficient for the evaluation of quasigeoid models of a centimetre accuracy (Krynski, 2005a, 2007; Krynski and Figurski, 2006). For example, the accuracy of height anomalies of the sites of the POLREF network was estimated as equal to 3-4 cm (Krynski, 2007). Thus, to assure the quality control of quasigeoid models, the 868 km long control GPS/levelling traverse running from SW part of Poland to NE borders, and consisting of 190 stations on levelling benchmarks, precisely surveyed with GPS, was established in the framework of that project (Cisak and Figurski, 2005). The accuracy of height anomalies of the sites of the control GPS/levelling traverse equals to 1-2 cm.

Quasigeoid models for Poland developed in the framework of the project (2002-2005) exhibit very high quality. Accuracy of the developed quasigeoid models evaluated by comparing quasigeoid heights with the respective ones on the sites of the GPS/levelling control traverse are in terms of the standard deviations as follows: 2.2 cm for the gravimetric quasigeoid, 2.0 cm for the gravimetric best-fitted quasigeoid, and 1.8 cm for the integrated quasigeoid (Krynski and Lyszkowicz, 2006a).

EGM96 was for a decade with no doubt the best global geopotential model and as such was widely used for modelling quasigeoid. The model was evaluated in different parts of the world and it was shown that its fit to the actual gravity field differs substantially. It has been considered that the EGM96 model approximates remarkably well gravity field in Poland (Krynski and Lyszkowicz, 2005a). The model compared with best quasigeoid models developed for the area of Poland exhibits the bias of ca. 50 cm, and standard deviation of 11.2 cm (Krynski, 2007). It is not surprising since mean 5' × 5' free-air gravity anomalies, computed in 1991 by PBG Ltd. (Exploration Geophysics Service) in Warsaw, were included to data set used for the development of the EGM96 model.

The progress in global geopotential modelling due to the contribution of growing amount of data from CHAMP and GRACE space missions, and in particular the development of the Earth Gravitational Model EGM2008 (Pavlis et al., 2008a, 2008b) of unprecedented resolution and accuracy, provides powerful and more reliable tools for evaluating regional geoid models as well as vertical components of GPS/levelling sites. Almost immediately after being publicly released, the EGM2008 model became a subject of extensive investigations by numerous research groups, starting with its evaluation. For example, it has been found that the EGM2008 represents a significant step forward in modelling gravity field in East Antarctica (Morgan and Featherstone, 2008); the difference between the EGM2008 and EGM96 geoid models in southern Africa are small for most of the region and reflect the improvement achieved by using a more detailed representation (Merry, 2008); new released combined model EGM2008 is relatively superior to other tested models in the Algerian region (Daho, 2009); EGM2008 is a good model over Australia because it can confirm the errors in the regional data (Claessens et al., 2009); without any doubt, EGM2008 model fits best to the existing GNSS/levelling height anomalies in Croatia (Liker et al., 2009); EGM2008 is superior to earlier global geopotential models over the northern Egypt and it provides there orthometric heights without any additional costs (Gomaa et al., 2009); EGM2008 agrees considerably better with GPS/levelling in Iran than any other global geopotential model (Kiamehr, 2009).

The results of evaluation of EGM2008, similarly to those obtained earlier for EGM96, show that its fit to the actual gravity field is not equally good all over the world. Evaluation of EGM2008 over Poland is thus important for estimating its usefulness for modelling regional gravity field as well as practical surveying involving GNSS heighting. It should be noted that the new set of mean 5' × 5' free-air gravity anomalies, computed in 2006 on the basis of point gravity data at the Institute of Geodesy and Cartography in Warsaw, was included to data set used for the development of the EGM2008 model

(Pavlis et al., 2008b). Therefore, one could expect good performance of that model over Poland.

The research conducted by the authors concentrated on the following:

– evaluation of the fit of EGM2008 to gravity field in Poland;
– assessment of quality of quasigeoid models in Poland with the use of EGM2008;
– detection of outlying heights of GPS/levelling sites of the POLREF and WSSG networks with the use of EGM2008.

2. Models investigated

Three quasigeoid models:

– GDQ08 - newest regional quasigeoid model for Poland developed in 2009 by combining gravity anomalies with the deflections of the vertical;
– quasi05c_corr - gravimetric quasigeoid model for Poland fitted to the heights of GPS/levelling sites of the POLREF network (Krynski and Lyszkowicz, 2006a, 2006b; Krynski 2007);
– GUGiK2001 quasigeoid model - the official quasigeoid model in Poland of the Head Office of Geodesy and Cartography (Pażus et al., 2002);

were used for the evaluation of the EGM2008 Zero Tide model together with the heights of GPS/levelling sites of the POLREF, EUVN, and WSSG networks (Krynski and Figurski, 2006) as well as the heights of the sites of the 868 km long GPS/levelling control traverse (Krynski 2007) (Fig. 1) established across Poland for quality control precise quasigeoid models.

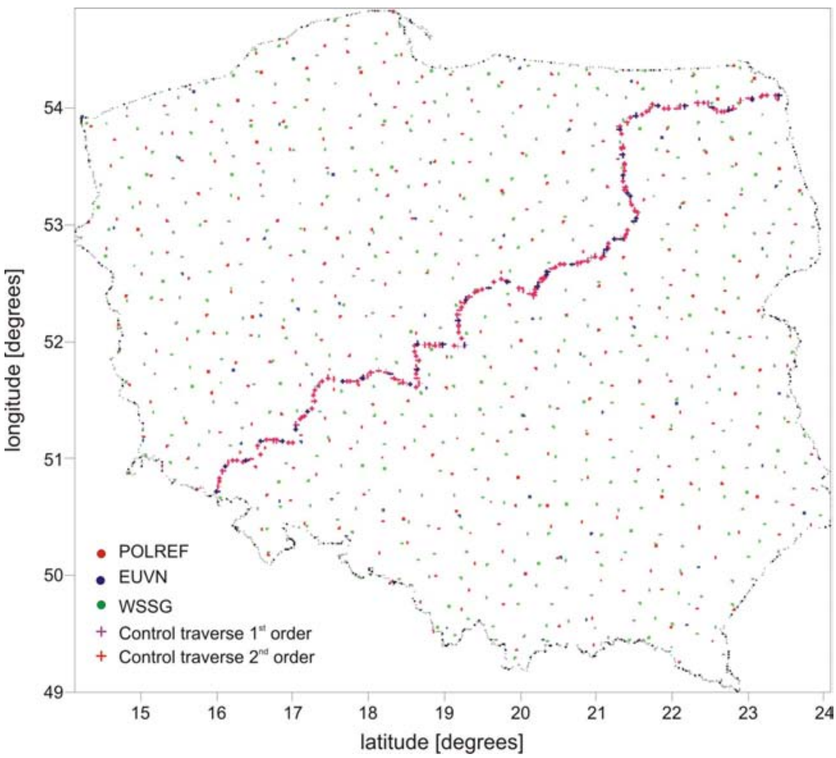

Fig. 1. Sites of the POLREF, EUVN, and WSSG networks as well as the GPS/levelling control traverse

43 stations of the GPS/levelling control traverse, considered as the 1st order control, were surveyed in one or two 24h sessions and the coordinates of those stations were determined using the EPN strategy with the Bernese v.4.2 program. The remaining 141 stations of the traverse, considered as densification points (2nd order), were surveyed in 4h sessions. The coordinates of those stations were calculated using the Pinnacle program with the 1st order control stations as reference (Krynski et al., 2005c; Cisak and Figurski, 2005).

2.1. EGM2008 Zero Tide geoid model

The new Earth Gravitational Model EGM2008, completed to degree 2160, has been developed by the National Geospatial-Intelligence Agency (NGA) (Pavlis et al., 2008a). This model, incorporates an improved version of 5' × 5' global gravity anomaly database, an improved

Geoinformation Issues
Vol. 1, No 1, 7-17/2009

ocean-wide set of altimetry-derived gravity anomalies, and has benefited from the latest GRACE-based satellite-only solutions (Pavlis et al., 2008b). EGM2008 provides an unprecedented resolution and accuracy, exposing even the smallest of incompatibility errors. The official Earth Gravitational Model EGM2008 has been publicly released in 2008 as Zero Tide model. This model contains additional coefficients extending to degree 2190 and order 2159. Full access to the model's coefficients and other descriptive files with additional details about EGM2008 are provided on web pages. All synthesis software, coefficients, and available pre-computed geoid grids assume a Tide Free system, as far as permanent tide is concerned.

2.2. GUGiK2001 quasigeoid model

GUGiK2001 quasigeoid model (Pażus et al., 2002) is the official quasigeoid model in Poland recommended by the Head Office of Geodesy and Cartography for surveying with the use of GNSS techniques. That model was determined by fitting the quasi97b quasigeoid model, developed using remove-compute-restore method with EGM96 (Lyszkowicz, 1998), to height anomalies at the POLREF, EUVN, WSSG GPS/levelling sites as well as height anomalies of GPS/levelling sites of the local TATRY network. GUGiK2001 model was developed in the form of 1' × 1' grid using cubic splines.

2.3. Quasi05c_corr quasigeoid model

Quasi05c_corr corresponds to the gravimetric quasigeoid model quasi05c, determined using remove-compute-restore method with EGM96, fitted to height anomalies of the GPS/levelling sites of the POLREF network, developed in 2005 in the framework of the project (Krynski and Lyszkowicz, 2006b; Krynski, 2007). The model was calculated with the use of a new set of mean gravity anomalies calculated in 2005 at the Institute of Geodesy and Cartography, Warsaw (Mank et al., 2006; Krynski, 2007). The fit was performed by the determination of its two components the trend and the signal. The trend was modelled by 3-parameter datum shift while the signal - with the use of empirical covariance function. Quasi05c_corr is given in the form of 1.5' × 3' grid.

2.4. GDQ08 geoid model

GDQ08 is a quasigeoid model, developed for Poland on the basis of the same gravity data as quasi05c but extended by the existing deflections of the vertical, using remove-compute-restore method with EGM2008. In the computation process the medium wavelength component represented by residual functionals of the anomalous potential (gravity anomalies and deflections of the vertical) was determined with the use of least squares collocation. GDQ08 is given in the form of 1.5' × 3' grid. The details concerning the development of the model were not published as yet.

3. Numerical tests

A number of numerical tests were conducted to evaluate the fit of EGM2008 to gravity field in Poland as well as to apply EGM2008 for quality assessment of quasigeoid models in Poland and for detection of outlying heights of GPS/levelling sites of the POLREF and WSSG networks.

3.1. Evaluation of the fit of EGM2008 to gravity field in Poland and quality assessment of local quasigeoid models

The method most commonly used for the assessment of quality of quasigeoid models is based on statistical analysis of residuals of height anomalies. For the following analysis the residuals of height anomalies were calculated at GPS/levelling sites of selected networks as a difference between GPS/levelling height anomalies and height anomalies obtained from quasigeoid models investigated.

The criterion of smallest standard deviation of residuals is usually used to indicate the best fitted model. However, dispersion, representing a difference between maximum and minimum value is also a very important parameter.

Quality of three selected quasigeoid models as well as EGM2008 quasigeoid was assessed using heights of GPS/levelling sites of the POLREF, EUVN, WSSG networks and the sites of the GPS/levelling control traverse. Height anomalies calculated using quasigeoid models investigated, i.e.

– $\zeta_{EGM2008}$ calculated for every point of interest (GPS/levelling site or grid point) using spherical harmonic coefficients of the EGM2008 model up to degree and order 2160;
– ζ_{GDQ08} of the GDQ08 model calculated as a sum of long- and medium-wave component obtained from the EGM2008 model and a short-wave component computed using least squares collocation on 1.5' × 3' grid and interpolated for every point of interest;
– $\zeta_{quasi05c\_corr\_corr}$ of the quasi05c_corr model interpolated for every point of interest from 1.5' × 3' grid;
– $\zeta_{GUGiK2001}$ of the GUGiK2001 model calculated for every point of interest using the GEOID program (Pażus, 2001) that interpolates quasigeoid heights from 1' × 1' grid;

were thus compared with the respective ones obtained from GPS/levelling.

Statistics (maximum, minimum, mean, standard deviation and dispersion) of obtained residuals for all models investigated, i.e.

$$\Delta\zeta_1 = \zeta_{GPS/levelling} - \zeta_{EGM2008}$$
$$\Delta\zeta_2 = \zeta_{GPS/levelling} - \zeta_{GDQ08}$$
$$\Delta\zeta_3 = \zeta_{GPS/levelling} - \zeta_{quasi05c\_corr}$$
$$\Delta\zeta_4 = \zeta_{GPS/levelling} - \zeta_{GUGiK2001}$$

are presented in Tables 1-4.

The standard deviation and dispersion as well as the mean are major statistics considered in the following analysis.

Before discussing the numerical results, in particular to evaluate the fit to GPS/levelling data in Poland of quasigeioid models investigated, it is necessary to recall that quasi05c_corr represents a gravimetric quasigeoid model fitted to the heights of GPS/levelling sites of the POLREF network, and GUGiK2001 represents a gravimetric quasigeoid model fitted to height anomalies at the POLREF, EUVN, WSSG GPS/levelling sites as well as height anomalies of GPS/levelling sites of a local TATRY network. It is also worth to mention that the systematic error was not removed from the quasigeoid model GDQ08 as well as to point out that all quasigeoid models investigated were developed with the use of terrestrial gravity data from Poland, however, each model is based on different gravity data set. Besides, EGM2008 and GDQ08, in contrast to quasigeoid models quasi05c_corr and GUGiK2001, do not incorporate any GPS/levelling data. GDQ08 is the only quasigeoid model to determine which the astronomic deflections of the vertical were applied.

The results presented in Tables 1-4 show that the quality of the EGM08 quasigeoid model over Poland corresponds remarkably well to that of the regional quasigeoid models investigated. The fit of height anomalies calculated from EGM2008 to GPS/levelling heights in Poland is almost as good as of height anomalies obtained from best regional quasigeoid models available. Standard deviations in Tables 1-4 indicate the GUGiK2001 quasigeoid model as best fitting one to GPS/levelling heights of the sites of the POLREF, EUVN, WSSG networks and GPS/levelling control traverse. Almost equally good performance exhibits the GDQ08 quasigeoid model that is not biased by the relatively large errors of heights of the POLREF sites.

Table 1. Statistics of residuals at points of the POLREF network [m]

Number of points	Statistics	$\Delta\zeta_1$	$\Delta\zeta_2$	$\Delta\zeta_3$	$\Delta\zeta_4$
342	Min	-0.050	0.010	-0.161	-0.038
	Max	0.186	0.238	0.149	0.147
	Mean	0.052	0.108	-0.009	0.015
	Std. dev.	0.037	0.033	0.039	0.022
	Dispersion	0.236	0.228	0.310	0.185

Table 2. Statistics of residuals at points of the EUVN network [m]

Number of points	Statistics	$\Delta\zeta_1$	$\Delta\zeta_2$	$\Delta\zeta_3$	$\Delta\zeta_4$
58	Min	-0.041	0.051	-0.126	-0.057
	Max	0.107	0.143	0.069	0.035
	Mean	0.030	0.086	-0.034	-0.011
	Std. dev.	0.027	0.021	0.039	0.020
	Dispersion	0.148	0.092	0.195	0.092

Table 3. Statistics of residuals at points of the WSSG network [m]

Number of points	Statistics	$\Delta\zeta_1$	$\Delta\zeta_2$	$\Delta\zeta_3$	$\Delta\zeta_4$
524	Min	-0.219	-0.153	-0.257	-0.253
	Max	0.281	0.327	0.170	0.201
	Mean	0.018	0.075	-0.043	-0.021
	Std. dev.	0.041	0.041	0.050	0.041
	Dispersion	0.500	0.480	0.427	0.454

Table 4. Statistics of residuals at points of the GPS/levelling control traverse [m]

Number of points	Statistics	$\Delta\zeta_1$	$\Delta\zeta_2$	$\Delta\zeta_3$	$\Delta\zeta_4$
184 points	Min	-0.036	0.033	-0.097	-0.077
1st & 2nd order	Max	0.065	0.126	0.012	0.029
	Mean	0.014	0.078	-0.037	-0.016
	Std. dev.	0.023	0.018	0.022	0.018
	Dispersion	0.101	0.093	0.109	0.105
43 points	Min	-0.018	0.054	-0.073	-0.048
1st order	Max	0.065	0.126	0.007	0.024
	Mean	0.025	0.088	-0.027	-0.006
	Std. dev.	0.020	0.017	0.021	0.016
	Dispersion	0.083	0.072	0.080	0.072

The GPS/levelling control traverse, due to highest accuracy of height anomalies of its sites, is among the GPS/levelling networks investigated the best and most reliable for the assessment of quality of quasigeoid models in Poland. The accuracy of height anomalies of the sites of GPS/levelling control traverse equals to 1 - 2 cm, while in case of the sites of the POLREF, EUVN and WSSG networks – equals to 3 - 4 cm (Krynski, 2007), 2 cm (Krynski and Figurski, 2006), and 6 - 7 cm (Krynski, 2007), respectively. In addition, height anomalies of GPS/levelling control traverse sites were not used for the determination of any of investigated quasigeoid models. Those accuracy estimates correspond to standard deviations of the fit of EGM2008 to GPS/levelling heights (Tables 1-4), i.e. 2.3 cm for the sites of the GPS/levelling control traverse, and 3.7 cm, 2.7 cm, 4.1 cm, for the sites of the POLREF, EUVN, and WSSG networks, respectively.

It is also worth to point out the impact of the use of EGM2008 when calculating long- and medium-wave component on the quality of regional geoid modelling. Comparison of results obtained for the GDQ08 model, based on the EGM2008 global geopotential model with those obtained for quasi05c_corr that was developed using the EGM96 global geopotential model shows that the standard deviations for GDQ08 are smaller at all investigated GPS/levelling networks. Moreover, at the sites of the GPS/levelling control traverse the dispersion for GDQ08 model is smaller than the one for the official quasigeoid model in Poland – GUGiK2001, developed using EGM96 (standard deviations for GDQ08 and for GUGiK2001 are equal).

The results obtained indicate that EGM2008 can be used for the assessment of quality of quasigeoid models in Poland. Further analysis concerned thus residual height anomalies corresponding to the differences between height anomalies of EGM2008 and the respective ones of GDQ08, quasi05c_corr, and GUGiK2001. To eliminate the effect of potential interpolation errors the residual height anomalies were calculated on 1.5' × 3' grid within the borders of Poland. Three sets each of 32 781 residuals were investigated. Statistics of obtained residuals, i.e.

$$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{GDQ08}}$$
$$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{quasi05c\_corr}}$$
$$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{GUGiK2001}}$$

are presented in Table 5.

Table 5. Statistics of residuals obtained for investigated grids [m]

Number of grid points	Statistics	$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{GDQ08}}$	$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{quasi05c\_corr}}$	$\zeta_{\mathrm{EGM2008}} - \zeta_{\mathrm{GUGiK2001}}$
32 781	Min	-0.008	-0.214	-0.164
	Max	0.130	0.620	0.275
	Mean	0.057	-0.060	-0.039
	Std dev.	0.017	0.039	0.028
	Dispersion	0.138	0.834	0.438

Distribution of obtained residuals is presented in Figures 2-4.

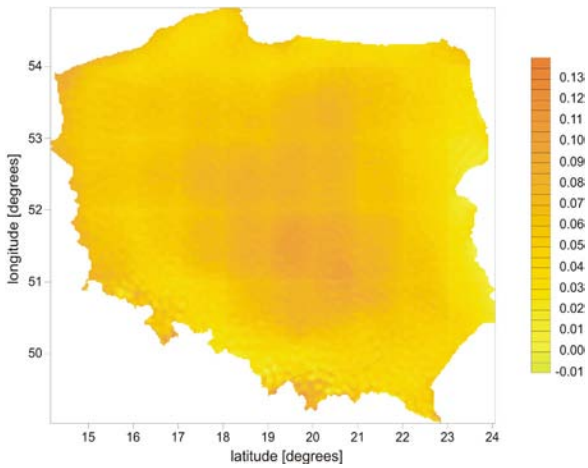

Fig. 2. Map of residuals $\zeta_{EGM2008}$ - ζ_{GDQ08}

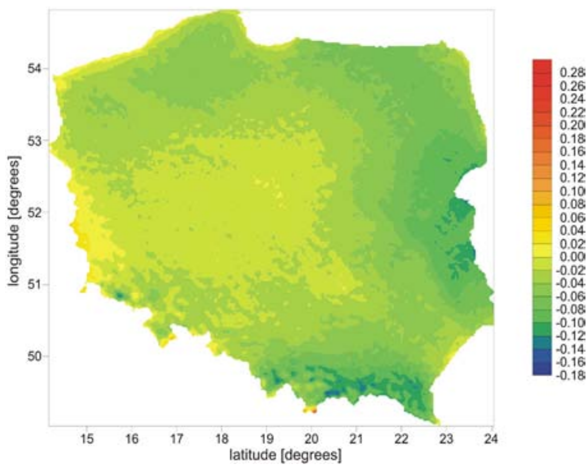

Fig. 3. Map of residuals $\zeta_{EGM2008}$ - $\zeta_{quasi05c\_corr}$

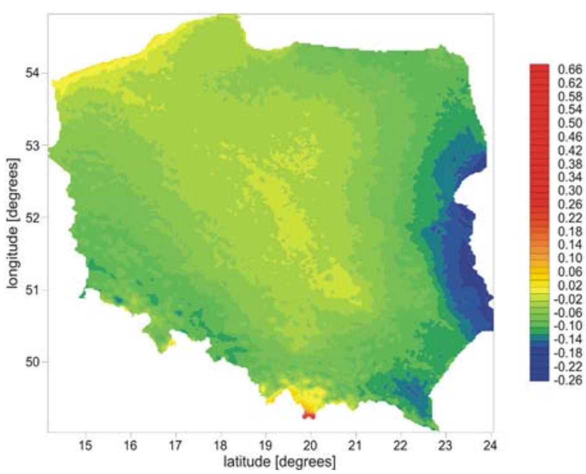

Fig. 4. Map of residuals $\zeta_{EGM2008}$ - $\zeta_{GUGiK2001}$

The statistics in Table 5 show that all quasigeoid models investigated fit very well to EGM2008. The standard deviation of residuals does not exceed 4 cm. The best fit represented by standard deviation of 1.7 cm and dispersion 13.8 cm exhibits the GDQ08 quasigeoid model. Slightly larger standard deviation and dispersion, i.e. 2.8 cm and 43.8 cm, respectively has been obtained for the GUGiK2001 quasigeoid model. The residuals increase with increasing elevation, what becomes more distinguished in case of GUGiK2001 and quasi05c_corr quasigeoid models. Maximum residuals are observed in high mountain region (Tatra Mountains). Large residuals obtained are caused by poor data coverage in that region. The statistics in Table 5 indicate a bias of 4 - 6 cm in regional quasigeoid models in Poland.

The results obtained are in agreement with the previous estimate of accuracy of regional quasigeoid models (Krynski, 2007) and confirm high quality of quasigeoid models in Poland.

EGM2008 provides a reference field model that is consistent with existing data quality and is likely adequate for most applications related to gravity field modelling in Poland.

3.2. Detection of outlying heights of GPS/levelling sites of the POLREF and WSSG networks with the use of EGM2008

Large dispersions of residuals noticeable for all quasigeoid models investigated at the sites of the POLREF and WSSG networks and simultaneously relatively small standard deviations (Tables 1-5) indicate the existence of outliers in ellipsoidal or/and normal heights of the sites. Since the EGM2008 model does not incorporate any GPS/levelling data, it is suitable for detection of outliers. The occurrence of largest differences between height anomalies calculated using GPS/levelling and quasigeoid models at the same sites for all models investigated indicates errors in heights rather than in quasigeoid models. To detect the outliers at the POLREF and WSSG networks, sites with residuals exceeding mean value enlarged by ±3 standard deviations, observed at least in two quasigeoid models, were analysed. Obtained results are presented in Tables 6-7.

Table 6. Points of the POLREF network with residuals exceeding mean value enlarged by ±3 standard deviations

Name of site	Quasigeoid model			
	EGM2008	GDQ08	quasi05c_corr	GUGiK2001
Koskowa	+	+	+	+
Spyrkowa		+	+	+
Jerzmanowice	+	+	+	+

Table 7. Points of the WSSG network with residuals exceeding mean value enlarged by ±3 standard deviations

Number of site	Quasigeoid model			
	EGM2008	GDQ08	quasi05c_corr	GUGiK2001
35	+	+	+	+
40	+	+		+
80	+	+	+	+
81		+		+
96	+	+	+	
109	+	+	+	+
149			+	+
167	+	+		+
296	+	+		+
322	+	+	+	+
372	+	+		+
380	+	+	+	+
399		+		+

Majority of detected outliers (Tables 6 and 7, Fig. 5) correspond with those obtained in previous evaluations of quasigeoid models for Poland (Osada et al., 2003; Krynski and Lyszkowicz, 2005c; Krynski, 2007).

All outliers in the POLREF network are at the sites in the central part Poland that were surveyed in two campaigns, i.e. in 1994 and 1995 (Krynski and Figurski, 2005, 2006). Out of thirteen outliers in the WSSG network only four sites are located near the borders of Poland, where the accuracy of a quasigeoid model can be lower. In the cases classified as outliers the residuals obtained can be treated as errors in normal or/and ellipsoidal heights of the respective sites of the POLREF and WSSG networks.

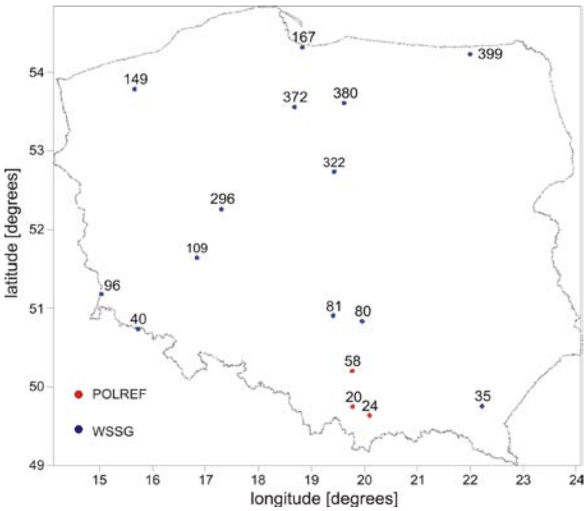

Fig. 5. Distribution of 3 points of the POLREF and 13 points of the WSSG network with residuals exceeding mean value enlarged by ±3 standard deviations

4. Conclusions

The investigation of the performance of the EGM2008 global geopotential model with the use of over 1000 GPS/levelling sites as well as regional quasigeoid models indicate remarkably good fit of EGM2008 to the gravity field over Poland.

The fit of EGM2008 to the POLREF, EUVN, WSSG and control traverse GPS/levelling sites, measured with standard deviation of the residuals of height anomalies, equals to 3.7 cm, 2.7 cm, 4.1 cm, and 2.3 cm, respectively, and with the mean of the residuals – representing the bias – equals to 5.2 m, 3.0 cm, 1.8 cm, and 1.4 cm.

The fit of height anomalies calculated from EGM2008 to GPS/levelling heights in Poland is almost as good as the height anomalies from best regional quasigeoid models available. EGM2008 can thus be used for quality assessment of regional quasigeoid models in Poland as well as for the detection of outlying heights of GPS/levelling sites.

The results of quality assessment of GDQ08, quasi05c_corr, and GUGiK2001 quasigeoid models, conducted with the use of the EGM2008 global geopotential model, are in agreement with the previous estimates based on GPS/levelling data, and confirm high quality of regional quasigeoid models in Poland. Standard deviation of the residuals of height anomalies, equals to 1.7 cm, 3.9 cm, and 2.8 cm, respectively, while the mean of the residuals – representing the bias – equals to 5.7 cm, –6.0 cm, and –3.9 cm.

The GDQ08 quasigeoid model as best fitted to EGM2008 as well as to height anomalies of the GPS/levelling control traverse can be considered the most accurate regional quasigeoid model in Poland at present.

Majority of outliers in height anomalies of sites of the POLREF and WSSG networks detected with the use of EGM2008 corresponds with those obtained in previous evaluations of quasigeoid models for Poland. The outlying residuals can be treated as errors in normal or/and ellipsoidal heights of the respective sites of the POLREF and WSSG network.

The comparison of the performance of EGM96 and EGM2008 as global geopotential models in remove-compute-restore technique of precise regional quasigeoid modelling in Poland indicates EGM2008 as the recommended one.

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Ocena jakości nowego globalnego modelu geopotencjału EGM2008 na obszarze Polski

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Streszczenie. W pracy przedstawiono wyniki oceny jakości nowego globalnego modelu geopotencjału EGM2008 na obszarze Polski. Model EGM2008, z którego wyeliminowano efekty pływowe, został także wykorzystany do oceny jakości trzech modeli quasigeoidy opracowanych w ostatniej dekadzie dla obszaru Polski. Obliczone z tego modelu anomalie wysokości zostały porównane z wynikami precyzyjnych pomiarów satelitarno-niwelacyjnych oraz z regionalnymi modelami quasigeoidy grawimetrycznej. Uzyskane wyniki potwierdzają wysoką jakość badanych modeli quasigeoidy i są zgodne z poprzednimi ocenami dokładności tych modeli. Regionalny model quasigeoidy obliczony dla obszaru Polski z modelu EGM2008 jest niemal równorzędny z istniejącymi precyzyjnymi modelami quasigeoidy. Model ten został wykorzystany do zidentyfikowania odstających anomalii wysokości pochodzących z precyzyjnych wyznaczeń satelitarno-niwelacyjnych wykorzystywanych do oceny jakości modeli quasigeoidy na obszarze Polski.

Słowa kluczowe: globalny model geopotencjału, regionalny model quasigeoidy, EGM2008