CENTIMETRE LEVEL OF ACCURACY OF QUASIGEOID MODEL IN POLAND

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Outline

1. Introduction

2. Data used

	g	ξ, η	H(lev)	h(GPS)	Δg(altim)	H_0(tide)	ρ	DTM
Quality analysis	●	●	●	●	●	●	●	●
Uniform standard, reference system	●	●	●	●	●			
Complimentary survey	●	●	●	●				
Databasis	●	●	●	●	●	●	●	●

3. Methodology

Most suitable geopotential model | Terrain corrections | Mean gravity anomalies | DTM - resolution and accuracy

4. Control

Control traverse

5. Quasigeoid models

Geoid models → Gravimetric, Astro-geodetic, GPS/levelling → Combined, Best fitted → Accuracy estimation, Future research

6. Conclusions

Introduction

Geoid/quasigeoid models in Poland

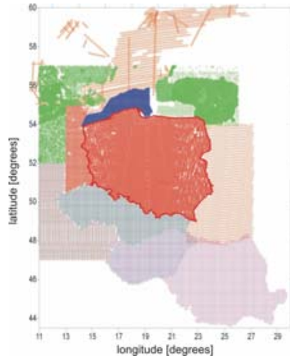
- **1949** - first **gravimetric** geoid model for the region of Central Europe, including Poland (accuracy **~3 m**)
- **1962** - first **astro-geodetic** geoid for Poland (accuracy **60 cm**)
- **1970** - first **astro-gravimetric** geoid for Poland (accuracy **30 cm**)
- **1993** - first **gravimetric** quasigeoid model for Poland, using the LS collocation combined with the integral method (accuracy **10 cm**)
- **1997** - **gravimetric** quasigeoid model for Poland, using the FFT technique (accuracy **5 cm**)

need for centimetre quasigeoid in Poland

2002-2005 - extensive research on precise geoid/quasigeoid model in Poland with the use of all available geodetic, gravimetric, astronomic, satellite and geological data

Data used (1)

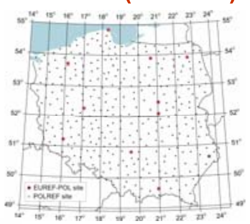
gravity data



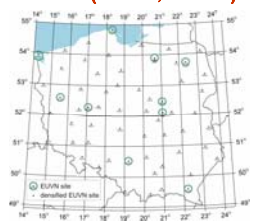
- **terrestrial** - point Δg (Poland) 1 089 062 (σ = 0.075 mGal)
  - mean Δg (neighbouring countries) (σ = 1.0 mGal)
- **marine** - Zaria – 1971 (σ = 2.0 mGal)
  - Turlejski – 1972 (σ = 2.0 mGal)
  - Petrobaltic – 1978/1980 (σ = 0.5 mGal)
  - Haakon Mosby – 2000 (σ = 2.6 mGal)
- **airborne** - KMS – 1999 (σ = 1.5 mGal)
- **altimetry** - ERS-1, GEOSAT – 1998 (σ = 4.0 mGal)

GPS/levelling data

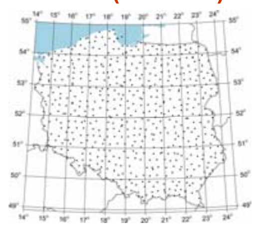
POLREF (1994-95)



EUVN (1997, 1999)



WSSG (1994-96)



- **POLREF** - 360 sites: $\delta\varphi$ (0.5-1.0 cm), $\delta\lambda$ (0.5-1.0 cm), δh (1.0-1.5 cm)
- **EUVN** - 52 sites: $\delta\varphi$ = 0.19 cm, $\delta\lambda$ = 0.22 cm, δh = 0.28 cm
- **WSSG** - 534 sites: $\delta\varphi$ = 2 cm, $\delta\lambda$ = 2 cm, δh = 3 cm

deflections of the vertical

- **astro-geodetic (1952-1975)** - 165: σ = 0.5”
- **astro-gravimetric (1960)** - 376: σ = 0.7”
- new **astro-geodetic (2003-2004)** - 29: σ = 0.3”

levelling data

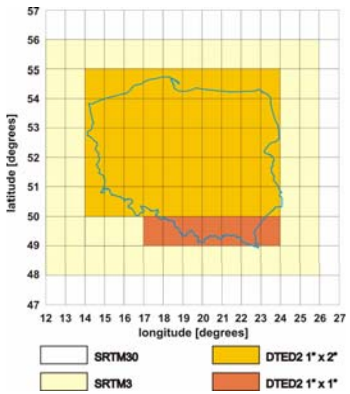
- **1999-2002 levelling campaign:** 382 levelling lines (total length 17 516 km, average length ~46 km)
  16 150 sections (average length 1.1 km), 135 loops, 245 nodal points

rms of lev. ±0.278 mm/km$^{1/2}$, rand. error ±0.264 mm/km$^{1/2}$, syst. error ±0.080 mm/km, σ of unit weight to ±0.088 mm/km

Data used (2)

digital terrain models

DTM	Resolution ['']	Vertical acc. [m]	Horizontal acc. [m]
DTED2	1 × 1 1 × 2	2-7	15
SRTM3	3 × 3	16	20
SRTM30	30 × 30		

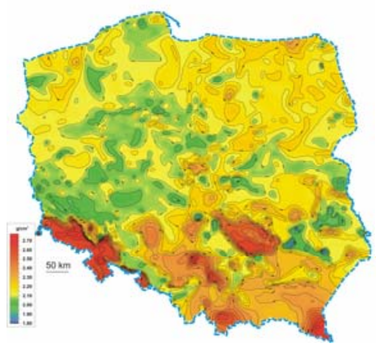


tide gauge data

25 tide gauges from Danish, Finnish, German, Polish and Swedish coast line
(monthly and annual means from at least 50 years)

lithosphere density data

- points of evaluated lithosphere density above the sea level (1363; 1/230 km^2)
- map of lithosphere density above the sea level (range 1.71- 2.76 gcm^{-3})
  mean = 2.17 gcm^{-3}; σ = 0.15 gcm^{-3}

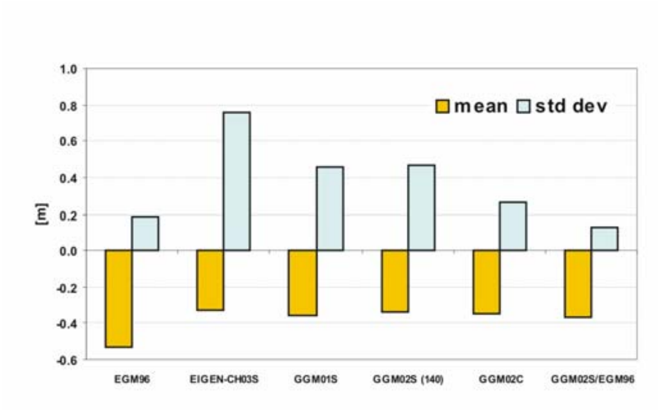


Geopotential models

Model	Degree	Type
EGM96	360	combined
EIGEN-CH03S	140	satellite only
GGM01S	120	satellite only
GGM02S (140)	160	satellite only
GGM02C	200	combined
GGM02S/EGM96	360	combined

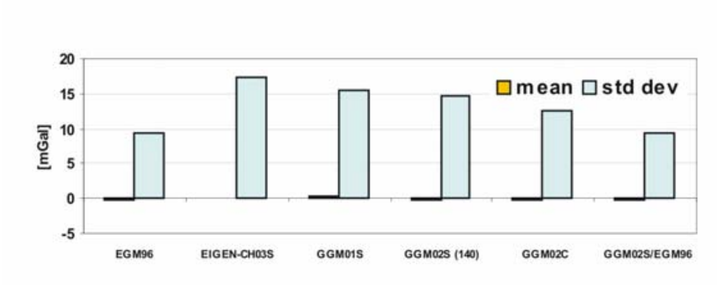
GM vs POLREF [m]

Model	Mean	Std dev.	Min	Max
EGM96	-0.53	0.19	-1.03	0.08
EIGEN-CH03S	-0.33	0.76	-2.22	1.06
GGM01S	-0.36	0.46	-1.70	1.05
GGM02S (140)	-0.34	0.47	-1.53	1.23
GGM02C	-0.35	0.26	-1.09	0.49
GGM02S/EGM96	-0.37	0.13	-0.79	0.05



GM vs Δg [mgal]

Model	Mean	Std dev.	Min	Max
EGM96	-0.18	9.39	-112.01	137.34
EIGEN-CH03S	0.00	17.30	-111.42	182.54
GGM01S	0.26	15.37	-109.94	166.07
GGM02S (140)	-0.14	14.81	111.89	157.57
GGM02C	-0.20	12.44	-115.57	153.86
GGM02S/EGM96	-0.30	9.31	-115.56	135.44

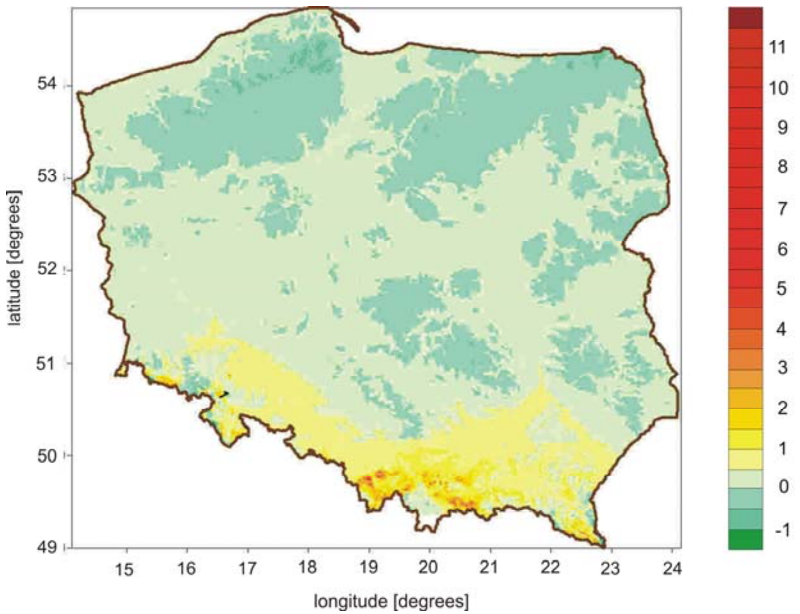


Terrain corrections

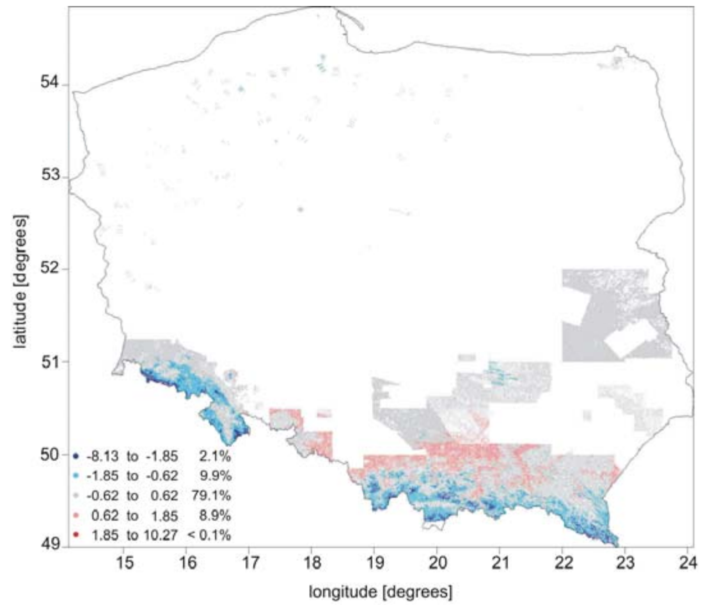
The optimum maximum integration radius [km] for different distortions of terrain elevation

Accuracy of the terrain correction [mGal]	Distortion Δh of terrain elev. relative to a gravity station [m]		
	15 (flat)	50 (hilly)	300 (mountainous)
0.1	14.60	205	280
0.2	22.0	118	295
0.3	60.0	33	246

Map of calculated "2005" ter. corr. at 1 078 046 gravity stations [mGal]



Differences between the "1992" and "2005" terrain corrections [mGal]



Number of stations	Min	Max	Mean	Std dev.
288 507	-8.135	10.260	-0.050	0.616

Mean gravity anomalies

1. Point free-air anomalies $\Delta g_{P'}^{F}$ on the geoid

$$\Delta g_{P'}^{F} = g_P + \delta g_P^F - \gamma_{P_0}$$
with $\delta g_P^F = 0.3086 \times h_P$

2. Point Faye anomalies $\Delta g_{P'}^{Faye}$ on the geoid

$$\Delta g_{P'}^{Faye} = \Delta g_{P'}^{F} + c_P$$

3. Point Bouguer anomalies $\Delta g_{P'}^{B}$

$$\Delta g_{P'}^{B} = \Delta g_{P'}^{Faye} - 2\pi\rho\, h_P$$

4. Interpolation of point <u>Bouguer anomalies</u> (Δg_i^{int}) and <u>terrain elevations</u> (h_i^{int}) on the grid of higher resolution then the resultant grid of mean Faye anomalies

5. Calculation of mean Bouguer anomalies $\overline{\Delta g}^{B}$ in 1' × 1' blocks

$$\overline{\Delta g}^{B} = \frac{1}{\sigma}\sum_i \Delta g_i^{int}\Delta\sigma$$

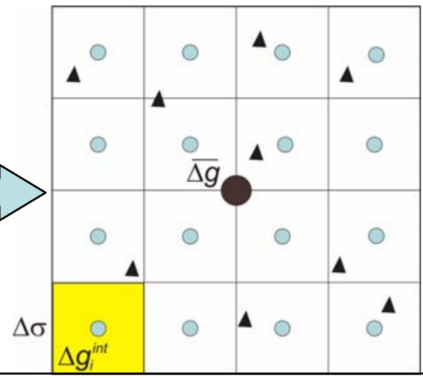
6. Calculation of mean heights $\bar{h}$ in 1' × 1' blocks

$$\bar{h} = \frac{1}{\sigma}\sum_i h_i^{int}\Delta\sigma$$

7. Calculation of mean Faye anomalies $\overline{\Delta g}^{Faye}$ in 1' × 1' blocks

$$\overline{\Delta g}^{Faye} = \overline{\Delta g}^{B} + 2\pi\rho\bar{h}$$

Concept of calculating mean gravity anomalies



Control traverse

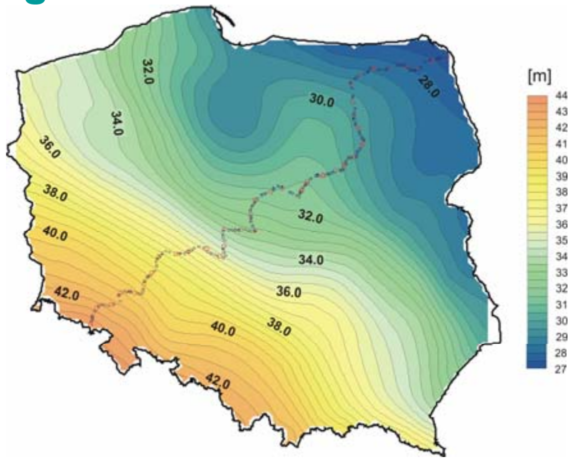
GPS/levelling traverse – stations at the benchmarks of 1st and 2nd order precise levelling network

868 km total length

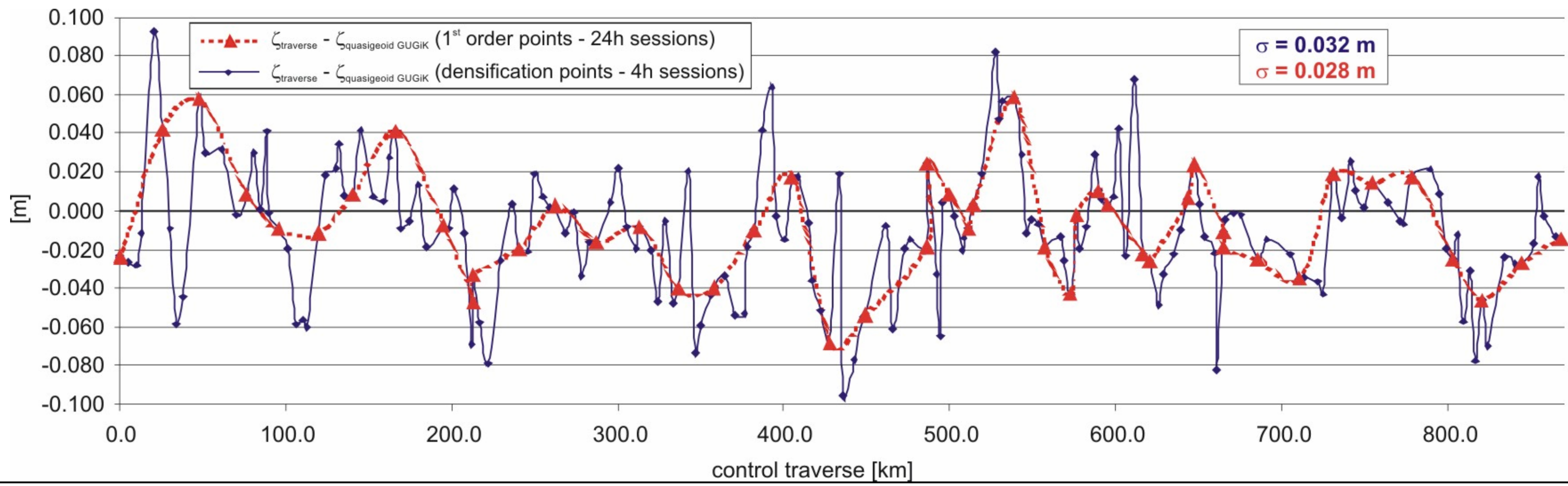
190 stations (every 4.6 km)

49 stations (24h or 2×24h)
(*determined using EPN strategy*)

141 stations (4h)
(*determined using 24h stations as fix*)



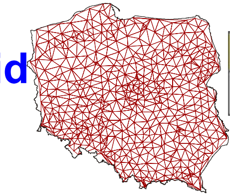
The fit of the heights of the control traverse to the GUGiK 2001 quasigeoid



Quasigeoid models developed

Astro-geodetic geoid

Astro-gravimetric geoid

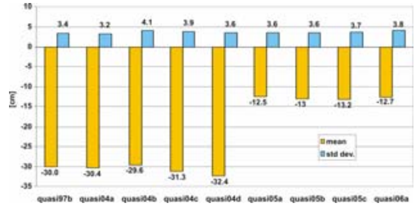


σ_{max}	$\sigma_{av.}$	σ_{min}
0.162	0.059	0.019

Gravimetric quasigeoid - different models (gravity data, GM, terr. corr)

fitting to the POLREF sites [cm]

Statistics	quasi04a	quasi04b	quasi04c	quasi04d	quasi05a	quasi05b	quasi05c	quasi06a
Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Std dev.	3.2	4.1	3.9	3.6	3.6	3.6	3.7	3.8
Min	-8.4	-12.0	-10.2	-10.5	-9.2	-9.2	-10.1	-10.3
Max	10.1	10.8	11.4	10.9	9.0	9.0	9.7	10.1



GPS/levelling quasigeoid - EUREF-POL, POLREF, EUVN, WSSG (kriging, min. curv.)

pure numerical [cm]

Statistics	Mean	Std dev.	Min	Max
$\zeta_{model} - \zeta_{EUVN}$	-3.4	4.8	-21.3	10.3
$\zeta_{model} - \zeta_{WSSG}$	-3.1	5.4	-16.7	21.6

with gravity support [cm]

Statistics	Mean	Std dev.	Min	Max
$\zeta_{model} - \zeta_{EUVN}$	-3.1	2.9	-12.4	2.1
$\zeta_{model} - \zeta_{WSSG}$	-3.2	5.5	-25.9	43.8

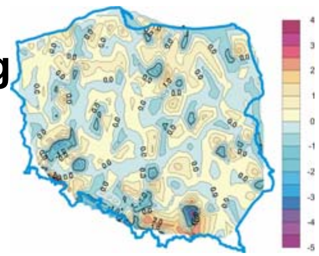
Integrated quasigeoid - GPS/levelling + gravity + terrain model

fitting to the POLREF, EUVN and WSSG sites [cm]

Statistics	Mean	Std dev.	Min	Max
$\zeta_{model} - \zeta_{POLREF}$	0.5	0.7	-1.3	3.0
$\zeta_{model} - \zeta_{EUVN}$	-0.5	0.6	-2.3	1.2
$\zeta_{model} - \zeta_{WSSG}$	-1.5	4.0	-24.3	38.9

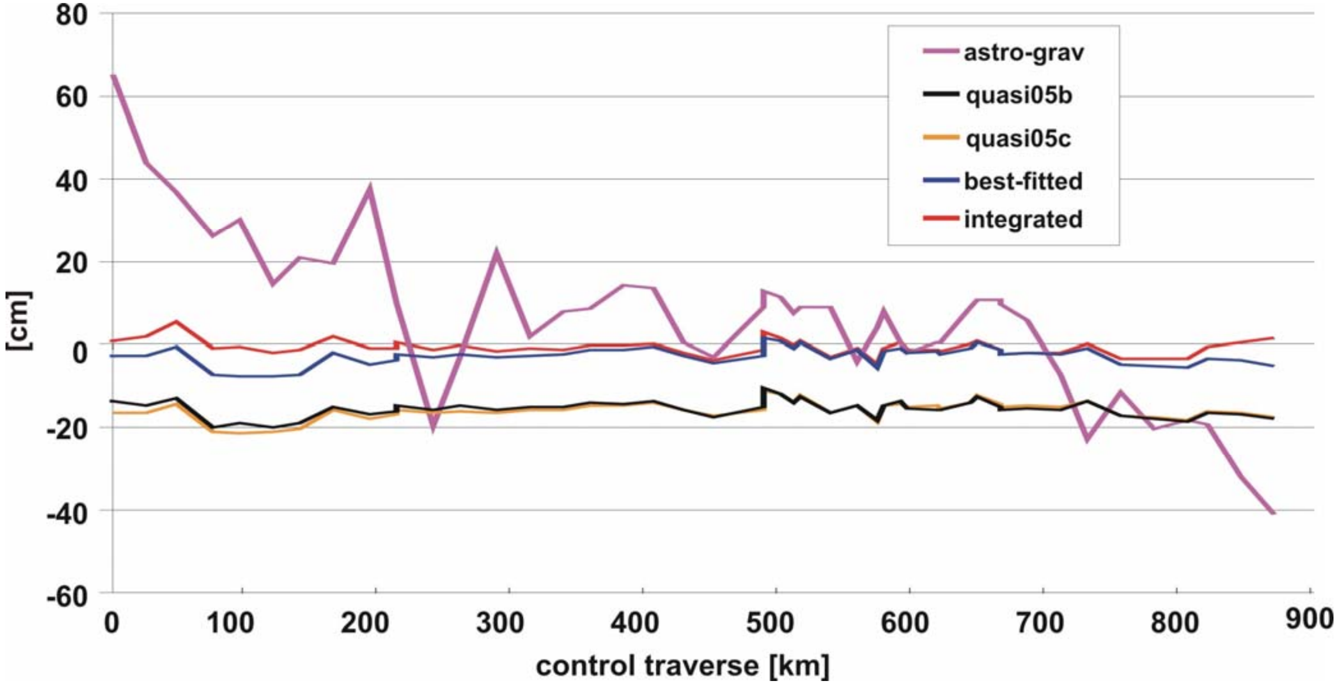
Best fitted quasigeoid - gravimetric quasigeoid fitted to GPS/levelling

The fit of „best fitted" quasigeoid model to the POLREF sites [cm]
(*mean difference: 1.0 cm*)



Quality of quasigeoid models

Fit of quasigeoid models to GPS/levelling control traverse [cm]



Model	Mean	Std dev.	Min	Max	N-E incl.
astro-geod.	8	21	-40	65	-0.15"
quasi05b	-15	2.1	-20	-11	~0
quasi05c	-16	2.3	-21	-11	~0
best-fitted	-2.7	2.0	-7.4	2.0	0.004"
integrated	-0.7	1.8	-4.7	5.4	-0.004"

Summary and conclusions (1)

- **All available data has been gathered, extensively qualitatively and quantitatively analysed, verified, and unified**

- **The data has been archived and appropriate databases were developed**

- **Precise terrain corrections were calculated for all gravity data**

- **Control GPS/levelling traverse established is a powerful tool for quality control of precise quasigeoid models in Poland**

- **Quality of heights of the POLREF sites is not sufficient for quality control of precise quasigeoid models in Poland**

Summary and conclusions (2)

- New **astro-geodetic** geoid model
  gravimetric quasigeoid models
  as well as **best fitted** quasigeoid model
  and **integrated** quasigeoid model based on gravity, GPS/levelling and topographic data
  were **developed**

- **Accuracy** of the developed **quasigeoid models** has been **evaluated**

astro-geodetic	21 cm
gravimetric	2.2 cm
best-fitted	2.0 cm
integrated	1.8 cm

- Developed **methods** and computing **strategies** as well as **experience** gained reflect **high potentiality for further research** on developing precise quasigeoid models in Poland