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OPTIMAL GEOPOTENTIAL MODELS OF THE EARTH'S GRAVITATIONAL FIELD FOR THE TERRITORY OF SOUTH-WESTERN BULGARIA - RILA MOUNTAIN

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ABSTRACT: *The subject of the study is to correctly select the most appropriate geopotential models of the Earth's gravitational field for the study area in order to make a more reliable assessment of the accuracy of local modelling of the geoid for the territory of Rila mountain.*

KEYWORDS: *Earth's gravitational field, Global gravity field model (GGM), accuracy assessment, EGM 2008, EIGEN-6C4.*

1. Introduction

Global models of the Earth's gravitational field are needed in solving various problems of space geodesy, geodynamics, geophysics, the theory of the figure of the Earth and others. Global geopotential models (GGMs) describe the Earth's gravitational field.

The GGMs data contain a limited set of dimensionless normalized harmonic coefficients that make it possible to calculate approximately the different functions of the Earth's gravitational potential in outer space. One of the main criteria for the effectiveness of these models is their accuracy, which in turn depends on the errors in determining the harmonic coefficients and the limited degree of spherical harmonics [1, 2].

For the purposes of the study, a comparison is made between the calculated height of the geoid $N_{GNSS/levelling}$ at 46 121 points with

GNSS/levelling data evenly distributed over the study area with corresponding values calculated using gravitational field models N_{GGM}.

2. Experimental results and discussion

2.1. Global assessment of the accuracy of GGMs

Today, there are more than 100 models of the Earth's gravitational field (GGM), which express the Earth's gravitational field and therefore the height of the geoid through functions of spherical harmonics. The International Center for Global Earth Surface Models (ICGEM) compares the heights of the geoids in accordance with the data obtained from the GNSS-levelling models in the USA, Canada, Europe, Australia, Brazil, Japan [3].

Table 1: Part of the GGM list presented on the ICGEM website

GGM	Year	Degree	Data
1	2	3	4
GGM05G	2015	240	S(Grace,Goce)
GOCO05s	2015	280	S(see model)
GO_CONS_GCF_2_SPW_R4	2014	280	S(Goce)
EIGEN-6C4	2014	2190	S(Goce,Grace,Lageous),G,A
ITSG-Grace2014s	2014	200	S(Grace)
GO_CONS_GCF_2_TIM_R5	2014	280	S(Goce)
GOGRA04S	2014	230	S(Grace,Goce)
EIGEN-6S2	2014	260	S(Goce,Grace,Lageous)
GGM05S	2014	180	S(Grace)
GOGRA02S	2013	230	S(Goce,Grace)
GGM05S	2014	180	S(Grace)
GOGRA02S	2013	230	S(Goce,Grace)
GOCO03S	2012	250	S(Goce,Grace...)
GO_CONS_GCF_2_DIR_R3	2011	240	S(Goce,Grace,Lageous)
GO_CONS_GCF_2_TIM_R3	2011	250	S(Goce)
AIUB-GRACE03S	2011	160	S(Grace)
GO_CONS_GCF_2_TIM_R2	2011	250	S(Goce)
GO_CONS_GCF_2_SPW_R2	2011	240	S(Goce)
GO_CONS_GCF_2_DIR_R1	2010	240	S(Goce)
GO_CONS_GCF_2_TIM_R1	2010	224	S(Goce)
GO_CONS_GCF_2_SPW_R1	2010	210	S(Goce)
EIGEN-51C	2010	359	S(Grace,Champ),G,A
AIUB-GRACE02S	2009	150	S(Grace)
EGM2008	2008	2190	S(Grace),G,A

Based on the results of the comparison made by the ICGE International Center, the best models of the Earth's gravitational field can be identified, which are presented in Table 2.

Analyzing the data given in Table 2, five global geopotential models can be identified from the list of currently available GGMs that will participate in the study. Table 3 gives the main characteristics of the selected models.

Table 2: Mean square values of geoid heights obtained by GNSS/levelling minus GGM (m)

GGM	Nmax	USA 6169 points (m)	Canada 2691 points (m)	Europe 1047 points (m)	Australia 201 points (m)	Japan 816 points (m)	Brazil 1112 points (m)	All 12036 points (m)
1	2	3	4	5	6	7	8	9
EIGEN-6C4	2190	0.247	0.126	0.121	0.212	0.079	0.446	0.235
EIGEN-6C3STAT	1949	0.247	0.129	0.121	0.213	0.078	0.447	0.236
EIGEN-6C2	1949	0.249	0.129	0.123	0.214	0.08	0.445	0.237
EIGEN-6C	1420	0.247	0.136	0.128	0.219	0.082	0.448	0.238
EGM2008	2190	0.248	0.128	0.125	0.217	0.083	0.460	0.239
GIF48	360	0.319	0.209	0.229	0.236	0.275	0.474	0.305
EIGEN-51C	359	0.335	0.234	0.248	0.234	0.312	0.476	0.321
EIGEN-5C	360	0.341	0.278	0.266	0.244	0.339	0.524	0.342
EIGEN-GL04C	360	0.339	0.282	0.309	0.244	0.321	0.541	0.346
GGM03C	360	0.347	0.337	0.301	0.259	0.316	0.513	0.356

Table 3: Description of selected GGMs

GGM	Description
EGM 2008	Combined model of the gravitational field with high resolution up to 2190 degree spherical harmonics. Contains the gravitational information obtained from a global database with average gravity anomalies for a 5'×5' grid. This grid is formed by grouping ground, altimetric data, satellite gravimetric mission data (GRACE) and satellite terrain data.
EIGEN-6C4	The latest combined model of the global gravitational field, published in 2014, **EIGEN-6C4** was calculated using satellite gravity gradiometric data for the entire GOCE mission from November 2009. to October 2013, (Floberghagen et al., 2011; Rummel et al., 2011), LAGEOS (Laser GEOdynamics Satellite) data from 1985 to 2010, GRACE data for ten years from 2003 to 2012, ground data derived from DTU12 ocean geoid data

	(Anderson et al., 2009) and EGM 2008 geoid grid height for continents. This model has a maximum spherical degree and order of 2190. This model has a spatial resolution of approximately 9 km.
EIGEN-6C3STAT	Combined model of the gravitational field, with high resolution, performed up to 1949 degree and order, using data GRACE, Lageos, the 4th execution of the GOCE mission and data from gravimetric and altimetric measurements. Released in 2014
EIGEN-6C2	The first combined model of the gravitational field, implemented to the extent and in order since 1946, using data from GOCE. The model belongs to GGM with high resolution. It is presented in 2012.
EIGEN-6C	The gravitational field model, implemented only to the extent of order 1420, calculated using data from GRACE, Lages and data from the GOCE mission. Presented in 2011.

In order to select the most suitable geopotential models for the study, a comparison is made between the heights of the geoid N_{GGM} and $N_{GNSS/levelling}$ calculated with the help of gravitational field models and, respectively, with the help of GNSS/ levelling data. The results of the comparison are presented in Table 4.

Table 4: Statistics on the difference between N_{GGM} and $N_{GNSS/levelling}$

GGM	L=M	Deviation			
		min	max	mean	SD
EGM2008	2190	0.141	0.961	0.676	0.171
EIGEN-6C4	2190	0.198	1.055	0.759	0.183
EIGEN-6C3STAT	1949	0.192	1.092	0.758	0.184
EIGEN-6C2	1949	0.194	1.103	0.767	0.186
EIGEN-6C	1420	0.286	1.177	0.808	0.190

The analysis of the data obtained when comparing GGMs allows to choose two models with at least standart deviation (SD). The models EGM2008 and EIGEN-6C4 will be used in the calculation of the local geoid on the territory of Rila mountain [4].

Taking into account the global estimates (Table 2), it can be noted that the EGM 2008 model ranks 5th. It follows that the global estimate does not always give a complete description of the gravitational model.

3. Conclusion

The model of the earth's gravitational field is the most important component in the definition of the gravimetric geoid. Therefore, the optimal geopotential model must be chosen correctly.

Global estimates of the Earth's gravitational field patterns are sometimes generally overly optimistic, and global statistics do not represent the region correctly. Therefore, the models of the earth's gravitational field must be evaluated specifically for the respective geographical region.

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