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GRAVIMETRIC MEASURMENTS IN EXTREMELY MOUNTAINOUS REGION OF THE TERRITORY OF SOUTH-WESTERN BULGARIA-RILA MOUNTAIN

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ABSTRACT: *The subject of the research is to perform gravimetric measurements in local extreme areas of the territory of South-western Bulgaria (S / W), and more precisely the north-western end of the Rila - Rhodope mountain massif - Rila mountain in order to analysis and evaluation the optimal option for practical modelling of the local geoid (quasi-geoid) in the area limited within the boundaries* $41^{0}52'06''N<\varphi<42^{o}21'22''N$ *and* $23^{0}01'11''E<\lambda<24^{o}01'05''E$.

The measured force of gravity in 287 gravimetric points an evenly distributed on the study area provides reliable gravimetric information that helps to deduce the surface of the local geoid for the Rila Mountains, where topographic effects completely dominate the local variations of the gravitational field.

KEYWORDS: *geoid, quasi-geoid, gravimetric measurement, extremely mountainous*

1. Introduction

There are two methods for studying the figure of the geoid [4]: 1) geometric (or astronomical-geodetic), is carried out by measuring the mutual position of points on the Earth's surface and the direction of the plumb line (triangulation and astronomical definitions); 2) physical (or gravimetric), is performed by measuring the acceleration the force of gravity. These methods differ significantly from each other: the first allows the study and determination of the figure of the geoid only on the basis of measurements carried out on a limited area of the earth's surface, and studies the figure corresponding to this area, and the second is applicable only when known the values of the acceleration the force of gravity at all points on the earth's surface, thus obtaining the whole figure of the geoid [2, 3, 6].

The gravimetric method is primarily expressed in the fact that it allows the connection of different reference coordinates and systems in a single system connected to the center of the earth's masses. The gravimetric method makes it possible to determine those parts of the gravitational field which cannot be detected by another method at present.

2. Experimental research

2.1. Analysis and evaluation of existing gravimetric points in the field of study limited to $41^{0}52'06''N<\varphi<42^{o}21'22''N$, $23^{0}01'11''E<\lambda<24^{o}01'05''E$

Based on a summary analysis of the existing initial gravimetric data for the territory of Bulgaria, a study of the current state and location of the points necessary to create a local model of the geoid for the study area within the boundaries of $41^{o}52'06''N<\varphi<42^{o}21'22''N$ and $23^{o}01'11''E<\lambda<24^{o}01'05''E$ [1, 7].

Fig. 1. The field of study limited within $41^{0}52'06''N<\varphi<42^{o}21'22''N$ and $23^{0}01'11''E<\lambda<24^{o}01'05''E$

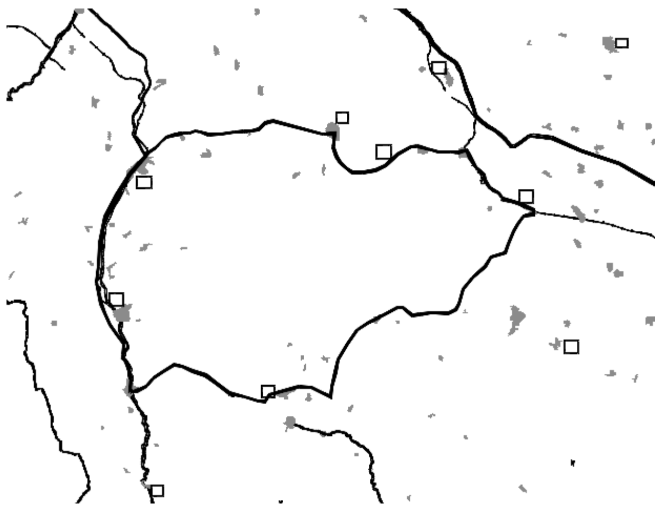
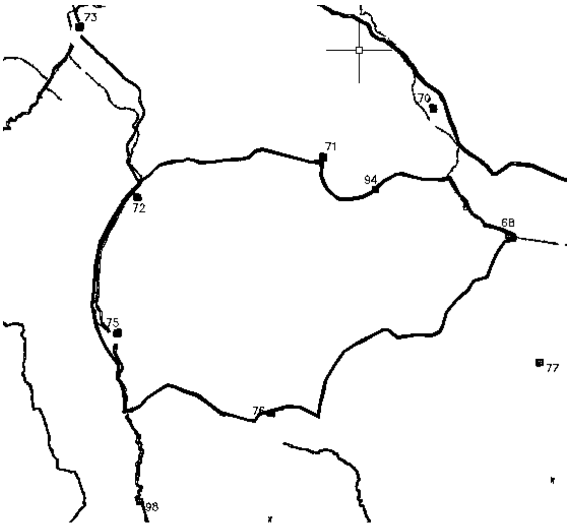


Fig. 2. Distribution of the points from the State Gravimetric Network of Bulgaria

3A

3B



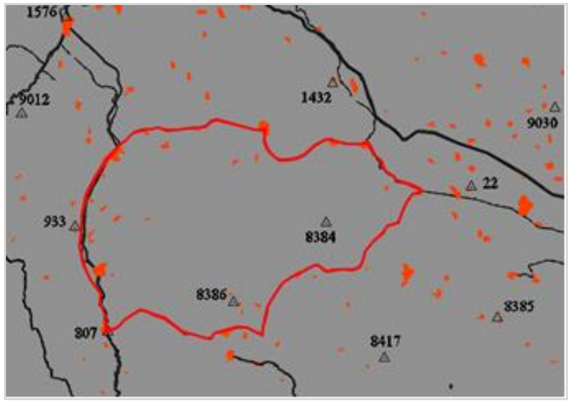


Fig. 3. Distribution of the points from the reference gravimetric network; 3B- The state GPS network

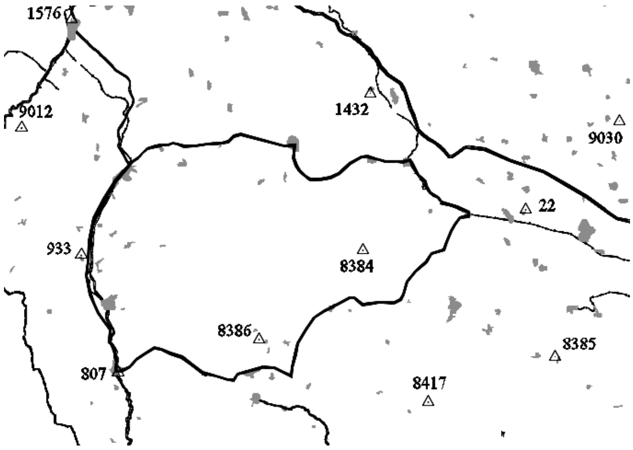


Fig. 4. Distribution of the points from the state GPS network

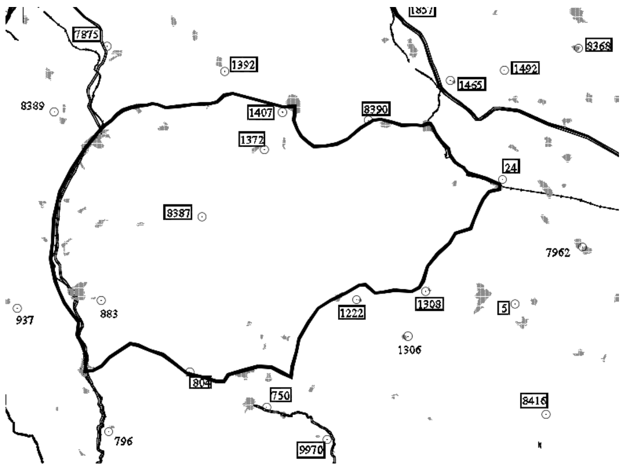


Fig. 5. Location of points with certain normal heights and secondary points of the state GPS network

Fig. 6. Location of EUVN-DA points. Points from BULREF and EUVN [7]

Most gravimetric measurements in Bulgaria were performed by the Committee of Geology and more precisely by the Enterprise for Geophysical Research and Geological Mapping /EGRandGM/. EGRandGM has created two Bougue scale anomaly maps 1:200 000 and 1:100 000. The distribution of the points with gravimetric measurements from the geological surveys for the study area is shown in Fig. 7, where it can be seen that there are parts on which no gravimetrical surveys were taken - these are Rila and Pirin mountains [5].

Fig. 7. Scheme of distribution of points with gravimetric measurements from the geological surveys carried out on the territory of South-western Bulgaria from 1951 to 2000 year.

2.2. Creating a database of gravimetric points in the study area

For the area limited in the range $41^{0}52'06''N<\varphi<42^{o}21'22''N$ and $23^{0}01'11''E<\lambda<24^{o}01'05''E$ gravimetric measurements were performed in order to analysis and evaluation the optimal option for obtaining a local model of the geoid for the study area [7].

The gravimetric flights were measured with relative static non-thermostated gravimeters models GAK-7T 388 and GAK-7T 396. These two gravimeters were calibrated on the calibration line of Bulgarian Academy of Sciences in August 2015 and the results are given in Table 1.

Table 1: Scale coefficients of gravimeters ГАК-7Т 388 and ГАК-7Т 396

Calibration period	**Temperature**	**Gravimeter**	**Scale factor**
August 2015 y.	28 degrees	ГАК-7Т 388	-7,6619
August 2015 y.	32 degrees	ГАК-7Т 396	-8,0738

The scale factor is influenced by the transport, atmospheric conditions and the amount of vacuum in the quartz system. Therefore, in the case of different multiple measurements of the sections in the polygon, different scale factors are obtained and the average result is taken from them. The non-linearity of the reporting scale also has an impact.

For starting points in the performed gravimetric measurements were used 6 points from the Reference Gravimetric Network of Bulgaria - Blagoevgrad, Dupnitsa, Samokov, Raduil, Belovo, Razlog. The force of gravity at the points of the Reference Network is determined relatively. The number of performed gravimetric flights is 69, as each of the flights includes up to 6 points and at least 2 control points of these 6 points. The total number of measured gravimetric points is 287 (Fig. 8). Table 2 presents the results of gravimetric measurements [7].

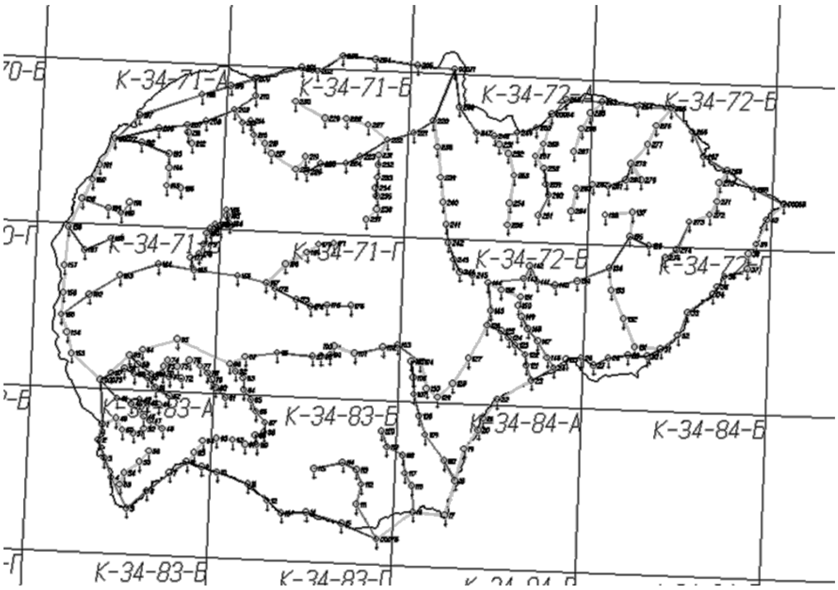


Fig. 8. Scheme of the performed gravimetric measurements in the studied area with the layout of map sheets M 1: 5000

Table 2: Carnet of gravimetric measurements

CARNET FOR GRAVIMETRIC MEASUREMENTS											
Point Name №		Time:			Reports			t ℃	Tool height (cm)		NOTES
		t_1 h min	t_2 min	$t_{кр.}$ min	$1^{ви}$	$2^{ри}$	КРАЕН		Relative to the	Relative to a point	Hits Embarrass-ment Fluctuations others
1	2	3	4	5	6	7	8	9	10	11	12
1	гт00075	9:18	18	18	4.667	4.664	4.670	21	0	0	
2	1	9:33	33	33	2.883	2.885	2.880	21	0	0	
3	2	9:50	50	50	3.047	3.059	3.054	21	0	0	
4	3	10:01	1	1	3.215	3.213	3.214	21	0	0	
5	4	10:14	14	14	3.665	3.664	3.662	21	0	0	
6	5	10:32	32	32	7.198	7.192	7.197	21	0	0	
7	6	10:53	53	53	7.671	7.678	7.681	21	0	0	
8	7	11:12	12	12	9.279	9.268	9.278	21	0	0	
9	8	11:25	25	25	11.688	11.694	11.698	21	0	0	
10	5	11:57	57	57	7.203	7.191	7.194	22	0	0	
11	3	12:22	22	22	3.210	3.210	3.214	22	0	0	
12	гт00075	12:40	40	40	4.696	4.679	4.685	22	0	0	
13											
14											
15											
Flight: **Gravimetric flight I** *гт 00075-1-2-3-4-5-6-7-8-5-3-гт 00075*					Weather: cloudy, windy			Gravimeter			ГАК-7Т388
								Гравим. t ℃			27
Date	12.06.2017 year.				Page.	1					

The gravimetric points are temporarily stabilized on the site with wooden stakes. They are selected in typical places on the ground. Only the points of the Reference Gravimetric Network are stabilized. The measurements were performed by a profile method with two gravimeters in order to obtain over-measurements of the differences in the force of gravity.

GNSS/levelling measurements were also performed in all 287 gravimetric points.

The alignment of the gravimetric measurements was performed, as the discrepancy in the closed gravimetric polygons was scattered in proportion to the time for the individual gravimetric flights (Table 3). This is due to the influence of the drift (zero shift) of the gravimeters on the measured differences in the force of gravity. The results were obtained in both gravimetric systems - Potsdam and IGSN71, as the mean square error per unit of weight is of the order of ±0.04 *mGal*, , and the discrepancy when closing the gravimetric flights is about 0.15 *mGal*.

Table 4 presents a sample of part of the calculation of the values of the acceleration of gravity from the measured differences in it.

Table 3: Gravimetric flight adjustment

CARNET

GRAVIMETRIC MEASUREMENTS

Observer: eng. Krasimira Kirilova — Data: 12.06.2017 — K = -7.661

Рейс: I — t нач = 9h 18min

От: г.т.00075 До: т.8 — t кр = 12h 40min — g изх = 980210.68 mGal

Гравиметър: .... ГАК - 7Т № **388**

№	№ point	Time h	min	report 1	report 2	report 3	Average report	Measured differences in g	Reduced time	Zero point correction	Corrected differences of g	Reduced differences of g	T °C	dH	reduction dH
1	гт00075	9	18	4.667	4.664	4.670	4.667	35.7539	0	0.0000	35.7539		27	0.000	0.0000
2	1	9	33	2.883	2.885	2.880	2.883	22.0841	15	-0.0112	22.0729	13.6722	27	0.000	0.0000
3	2	9	50	3.047	3.059	3.054	3.053	23.3916	32	-0.0239	23.3677	-1.3089	27	0.000	0.0000
4	3	10	1	3.215	3.213	3.214	3.214	24.6225	43	-0.0321	24.5904	-1.2338	27	0.000	0.0000
5	4	10	14	3.665	3.664	3.662	3.664	28.0674	56	-0.0418	28.0256	-3.4424	27	0.000	0.0000
6	5	10	32	7.198	7.192	7.197	7.196	55.1260	74	-0.0552	55.0708	-27.0573	27	0.000	0.0000
7	6	10	53	7.671	7.678	7.681	7.677	58.8109	95	-0.0709	58.7401	-3.6868	27	0.000	0.0000
8	7	11	12	9.279	9.268	9.278	9.275	71.0558	114	-0.0850	70.9707	-12.2469	27	0.000	0.0000
9	8	11	25	11.688	11.694	11.698	11.693	89.5826	127	-0.0947	89.4879	-18.5224	27	0.000	0.0000
10	5	11	57	7.203	7.191	7.194	7.196	55.1286	159	-0.1186	55.0100	34.4483	27	0.000	0.0000
11	3	12	22	3.210	3.210	3.214	3.211	24.6020	184	-0.1372	24.4648	30.5305	27	0.000	0.0000
12	гт00075	12	40	4.696	4.679	4.685	4.687	35.9046	202	-0.1507	35.7539	-11.3031	27	0.000	0.0000
13															
14															
15															
16															
17															
18															
19															
20															

dH is positive when the gravimeter is above the reference and is added to the measured g

Table 4: Calculation of the values of the acceleration of the force of gravity from the measured differences in it with gravimeters ГАК-7Т № 388 and №396

гравиметрична система IGSN 1971г

изходна	нова	g изх.	388	396	средно	g изм.	dgH1	dgH2	g изч.
гт 00075	1	980210.68	13.672	13.932	13.802	980224.48	0.00	0.00	**980224.48**
1	2	980224.48	-1.309	-1.178	-1.244	980223.24	0.00	0.00	**980223.24**
2	3	980223.24	-1.234	-1.277	-1.256	980221.98	0.00	0.00	**980221.98**
3	4	980221.98	-3.442	-3.640	-3.541	980218.44	0.00	0.00	**980218.44**
4	5	980218.44	-27.057	-26.921	-26.989	980191.45	0.00	0.00	**980191.45**
5	6	980191.45	-3.687	-3.729	-3.708	980187.74	0.00	0.00	**980187.74**
6	7	980187.74	-12.247	-12.213	-12.230	980175.52	0.00	0.00	**980175.52**
7	8	980175.52	-18.522	-18.499	-18.511	980157.00	0.00	0.00	**980157.00**
8	9	980157.00	-15.988	-15.702	-15.845	980141.16	0.00	0.00	**980141.16**
9	10	980141.16	-22.429	-22.606	-22.517	980118.64	0.00	0.00	**980118.64**
10	11	980118.64	-36.866	-36.819	-36.843	980081.80	0.00	0.00	**980081.80**
11	12	980081.80	-22.081	-22.014	-22.048	980059.75	0.00	0.00	**980059.75**
12	13	980059.75	-15.396	-14.976	-15.186	980044.57	0.00	0.00	**980044.57**
13	14	980044.57	27.884	28.395	28.140	980072.71	0.00	0.00	**980072.71**
14	15	980072.71	11.444	11.839	11.642	980084.35	0.00	0.00	**980084.35**
15	гт 00076	980084.35	-4.047	-3.707	-3.877	980080.47	0.00	0.00	**980080.47**

г. т. 00075 - Благоевград - g $_{IGSN71}$ = 980210.68 mGal

г. т. 00076 - Разлог - g $_{IGSN71}$ = 980080.47 mGal

3. Conclusion

When applying the gravimetric method in the study of the external gravitational field on a local scale requires uniform coverage over the entire surface of the study area with gravimetric measurements, it is important to have sufficient gravimetric data. Of course, this is an impossible task of the method in alpine areas.

The conducted gravimetric measurements on the territory of Rila mountain will be used for control measurements using data from the gravimetric map of Bouge anomalies in M 1: 200 000 for the territory of Bulgaria in order to model the geoid (quasi-geoid) for the studied local area.

The subject of further research is a proposal for solving the current problem of local modeling of the geoid for the high mountain regions of Bulgaria in particular for the North-western end of the Rila-Rhodope mountain massif - Rila mountain by the method Astronomy-gravimetric levelling or GNSS/levelling.

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