Gravity Variation at the Moscow Fiducial Station

V.I. Kaftan[1]

Introduction

Precise absolute gravity observation is one of important tasks of global or regional geodetic reference networks. Some permanent stations of these networks are equipped by the absolute gravimeters having an accuracy of a few microGal. The Moscow fiducial station includes several GPS observation sites and the main gravimetric point of Russia. The absolute gravity measurements at this point are stared from the beginning of 1980th. Now the considerably long time series of gravity values are collected. This result allows us to analyze it and to make an attempt to receive a better knowledge of a temporal gravity behavior.

Time series of G

The first gravity measurement at the Moscow point was done by the Russian absolute ballistic laser gravimeter GABL in August 1980. This gravimeter was a prototype of the modern model of Russian stationary gravimeters GBL and it's transportable variants GBL-P. From the end of 1980th gravity measurements are performing by GBL models. Every year measurements were repeated from 8 to 27 times. About 200 repetitions are collected for today. The precision of the measurements varies from 2 to 6 microGal corresponding with a seismic noise level and a model of instrument. The plot of the gravity changes is shown at the Figure 1. Seven different gravimeters were used in the observation period (see Table 1).

As it is shown in the table the mean long-term results for every gravimeter vary significantly. These mean values differ from 5 to 24 microGal. There is nothing unexpected in this result. Absolute gravity values obtained using different gravimeters can differ significantly due to systematic biases and temporal environmental variation unremoved from measuring results (Sakuma, 1973, Marson et al, 1995). The measured results were used for the statistical analysis aimed to the estimation of possible linear and periodic components.

[1] Vladimir I. Kaftan: Central Research Institute of Geodesy, Aerial Surveying and Cartography, Onezhskaia 26, 125413 Moscow, RUSSIA, e-mail: kaftan@geod.ru

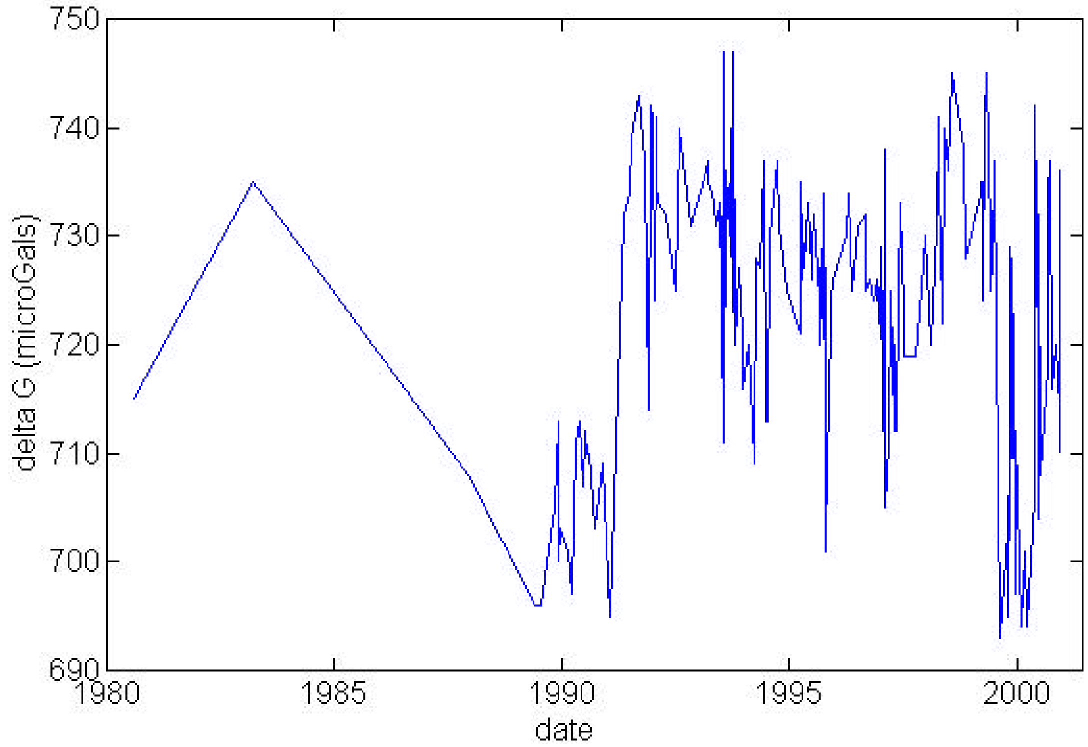

Fig.1. Results of absolute gravity determination at the Moscow fiducial station

Table 1. Mean gravity values measured by different gravimeters

Type of gravimeter	Mean DG	R.M.S. residuals	Number of measurements
GBL No1	725.8	15.4	26
GBL No2	704.2	5.1	8
GBL No3	727.6	10.6	99
GBL No4	722.4	7.0	7
GBL No5	714.0	-	1
GABL	719.3	14.0	3
GBL-P	712.0	10.3	46

Analysis of hidden periodisities

The periodicity analysis technique based on the iteration least squares method was used for mathematical modelling. The method allows one to determine the trend component and the set of harmonics in the series both of regular and irregular observations.

Two steps of computations were used: 1) estimation and removal of the trend (linear component), 2) finding one after another and removal of the high amplitude periodical components (harmonics), twice exceeded their standard errors. After a trend component has been eliminated the observation set is approximated by a periodical function. Error equations to the approximate values of unknown oscillation parameters are solved in succession for every harmonic (beginning with the highest amplitude) with the use of lest square technique. As the precise values of coefficients of error equations are not known a priori, an estimation of the harmonic parameters is carried out by an iterative approach. Least square solution of the error equations is repeated until the two consecutive solutions are differed by a small value, which we take equal to 10^{-7}.

By this solution not only the most probable values of amplitudes, phases and periods of the proper harmonic component are estimated, but also the mean square errors (or residuals) of this estimations are determined using known formulas of the Lest Square Method. When the first high-amplitude harmonic has been determined, the obtained sinusoidal function is subtracted from the initial time series, and the set of remainders is used for the determination of the next harmonic, etc.

This procedure allows us to estimate, in sequence, parameters of the dominant high amplitude harmonics and their standard errors. From a total amount of the estimated harmonics only those with amplitudes more than two times over their standard errors are selected and used for mathematical modelling. The final model is a polyharmonical function that has the best fitting to the initial time series.

The described technique was used for the results obtained by the three different gravimeters GBL No1, GBL No3, and GBL-P separately. The results of the hidden periodicity analysis are presented in the Table 2. The interesting fact is that several dominated harmonics close each other mostly for every parameter: period, amplitude, and phase. The close harmonics are placed in a one row of the table. In the most cases their closeness is in a 3-sigma (3 r.m.s.) margins. These facts demonstrate a high probable physical existence of these fluctuations.

Table 2. Comparison between dominated harmonics of gravity and excess length of day oscillations

	GBL No3			GBL-P			GBL No1			LODs		
Ampl. A (mGal)	**Period T (years)**	**Phase (year)**	**Ampl. A (mGal)**	**Period T (years)**	**Phase (year)**	**Ampl. A (mGal)**	**Period T (years)**	**Phase (year)**	**Ampl. A (msec)**	**Period T (years)**	**Phase (year)**	**T (days)**
									1.0+0.1	22.4+1.8	89.7+1.2	
									0.19+0.04	0.076+0.00	98.99+0.01	27.8
4.2+1.4	2.49+0.09	98.1+0.3	7.1+1.2	2.68+0.12	97.6+0.3	13.4+3.0	2.75+0.13	96.6+0.2	0.11+0.03	2.39+0.07	97.5+0.5	
3.8+1.3	1.03+0.02	98.30+0.13	2.9+1.0	1.02+0.02	98.45+0.11	2.1+1.4	0.97+0.04	98.14+0.14	0.5+0.04	1.0+0.01	98.82+0.06	
2.0+1.0	0.49+0.01	98.93+0.07	4.8+1.4	0.45+0.003	98.92+0.04				0.20+0.02	0.50+0.001	98.67+0.04	
3.4+1.2	0.38+0.002	98.82+0.05							0.14+0.04	0.34+0.001	98.99+0.06	
						4.7+2.5	0.64+0.01	98.86+0.07				
2.1+1.1	0.044+0.000	98.96+0.01	3.0+1.0	0.044+0.000	98.956+0.01	3.8+1.8	0.044+0.00	98.96+0.01	0.09+0.03	0.047+0.00	98.97+0.01	16.4
1.8+0.9	0.043+0.000	98.957+0.00	2.6+0.8	0.043+0.000	98.97+0.01	2.0+0.8	0.043+0.00	98.98+0.01				15.7
1.8+1.0	0.16+0.001	98.85+0.03	2.5+0.7	0.14+0.000	98.84+0.01	8.6+2.2	0.14+0.000	98.88+0.01				55
2.2+0.9	0.020+0.000	98.996+0.00	1.4+0.7	0.019+0.000	98.997+0.01	3.7+1.7	0.018+0.00	98.992+0.00	0.11+0.04	0.019+0.00	98.986+0.0	6.9
3.1+1.2	1.58+0.05	97.8+0.24	1.1+0.6	1.93+0.13	98.0+0.33	1.7+1.0	1.76+0.15	97.6+0.31	0.10+0.03	1.83+0.04	98.9+0.33	
1.8+0.9	0.17+0.001	98.98+0.04	1.2+0.5	0.13+0.000	98.99+0.02	3.8+1.3	0.13+0.000	98.96+0.01				55
2.5+1.2	0.11+0.001	98.90+0.02	1.4+0.6	0.11+0.000	98.96+0.02							40
2.9+1.1	0.22+0.001	98.78+0.03				2.6+1.0	0.20+0.01	98.81+0.03	0.14+0.04	0.20+0.000	98.77+0.04	77
1.8+0.9	0.023+0.000	98.986+0.00	1.2+0.6	0.020+0.000	98.988+0.01	3.4+1.6	0.020+0.00	98.985+0.00	0.07+0.03	0.021+0.00	99.00+0.01	7.7
1.7+1.1	0.034+0.000	98.99+0.01	2.2+0.8	0.034+0.000	98.97+0.01							12.4
1.8+0.9	0.65+0.01	98.69+0.15				2.0+1.2	0.62+0.02	98.59+0.08	0.07+0.03	0.62+0.01	98.89+0.17	
1.9+1.1	0.44+0.01	98.69+0.09										
1.8+0.9	0.79+0.02	98.27+0.15							0.09+0.03	0.76+0.01	98.11+0.19	
2.3+0.8	6.0+0.6	98.3+0.7				2.0+1.1	5.3+0.8	97.8+0.6	0.06+0.03	5.0+0.5	97.5+1.5	
1.4+0.8	10.7+3.8	89.5+2.6							0.06+0.03	12..3+3.0	89.1+3.8	
									0.08+0.03	0.21+0.001	98.87+0.05	
									0.07+0.03	0.30+0.001	98.92+0.10	
									0.09+0.03	0.84+0.01	98.87+0.19	

The next step of the analysis was a comparison between determined gravity variations and variations of the length of the day (LODs). For this purpose the LOD values presented in the International Earth Rotation Service Bulletin were analyzed using the technique described above. The revealed harmonics are presented in the Table 2.

Periodicities in the Earth's rotation were studied thoroughly by many authors. Some of this variations are described, an example, by Bursa and Pec (1993). The known annual, semi-annual, fortnightly and monthly variations have amplitudes of about 0.5 msec, 0.3 msec, 0.36 msec, and 0.19 msec, respectively. Our estimations quite close to these excepting the fortnightly harmonic which amplitude has determined four times lover (16.4 days, amplitude 0.09 msec).

The comparison (see Table 2) has shown that there were some LODs harmonics having periods close to gravity ones. These obtained harmonics of the gravity and the length of the day are divided to two main groups of approximately co-phased and antiphased harmonics painted different colors (Table 2). The phase comparison is presented in the Table 3.

Table 3. Phase comparison between g and LODs

Type of harmonic	Mean period (years) T_m	Mean phase difference (years) $\lvert j_{gmean}-j_{lods}\rvert$	$\lvert j_{gmean}-j_{lods}\rvert/T_m$	Relative error
Co-phased	2.58	0.07	0.03	3%
	0.045	0.01	0.22	22%
	0.21	0.03	0.14	14%
	0.78	0.16	0.21	21%
	5.4	0.55	0.10	10%
	11.5	0.8	0.07	7%
Antiphased	1.00	0.52	0.52	4%
	0.48	0.26	0.54	8%
	0.36	0.17	0.47	6%
	0.019	0.009	0.47	6%
	1.78	1.1	0.62	24%
	0.021	0.014	0.67	34%
	0.63	0.25	0.40	20%

The phase comparison shows that some gravity oscillations can be partly explained by the Earth's rotation changes. But the origin of another harmonics is difficult to describe. In any cases the statistical analysis and comparison performed provide the basis for the better understanding of the temporal gravity variations.

Conclusion remarks

The brief description of the hidden periodicity analysis in the absolute gravity measurements at the Moscow fiducial station shows the considerable usefulness of the approach accepted.
The problem of extracting a good corrected gravity value is rather significant for the high precision reference networks. These networks have to give a good basis for the solving of the more geodetic tasks such as a precise positioning, a precise geoid determination, a calibration of measurement equipment, a precise geodetic datum definition, a determination of heights, a monitoring of position and gravity variations etc.
Author hope that the result described would encourage geodesists and especially owners of permanent geodetic stations and absolute gravimeters to cooperate for a global (or regional) scale experiment on synchronous repeated absolute gravity measurements at the permanent GPS stations.

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