



Gravity measurements in the Moscow gravity network

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Introduction

The metrological local precise gravity networks are created to calibrate relative gravimeters, to test absolute gravimeters (AG) and to improve methods of performing and processing gravity measurements. We report on the gravity measurements campaign in the Moscow Gravity Network in Spring 2015. The major goals of this campaign were to determine:

- linear scale-factors for relative gravimeters,
- gravity at all stations w.r.t. International Comparisons of Absolute Gravimeters (ICAG2013),
- offsets of the AG which did not participate in Russian–Finnish Comparisons of Absolute Gravimeters (RFCAG2013).

1. Network

The Moscow Gravity Network consists of six stations (see Fig.1): TsNIIGAIK, Zvenigorod, Krasnaya Presnya, Ledovo, Troitse-Seltso, Mendeleevo. The largest gravity difference is about 52 mGal. All stations are permanent and have gravity values from absolute measurements which are usually repeated annually.

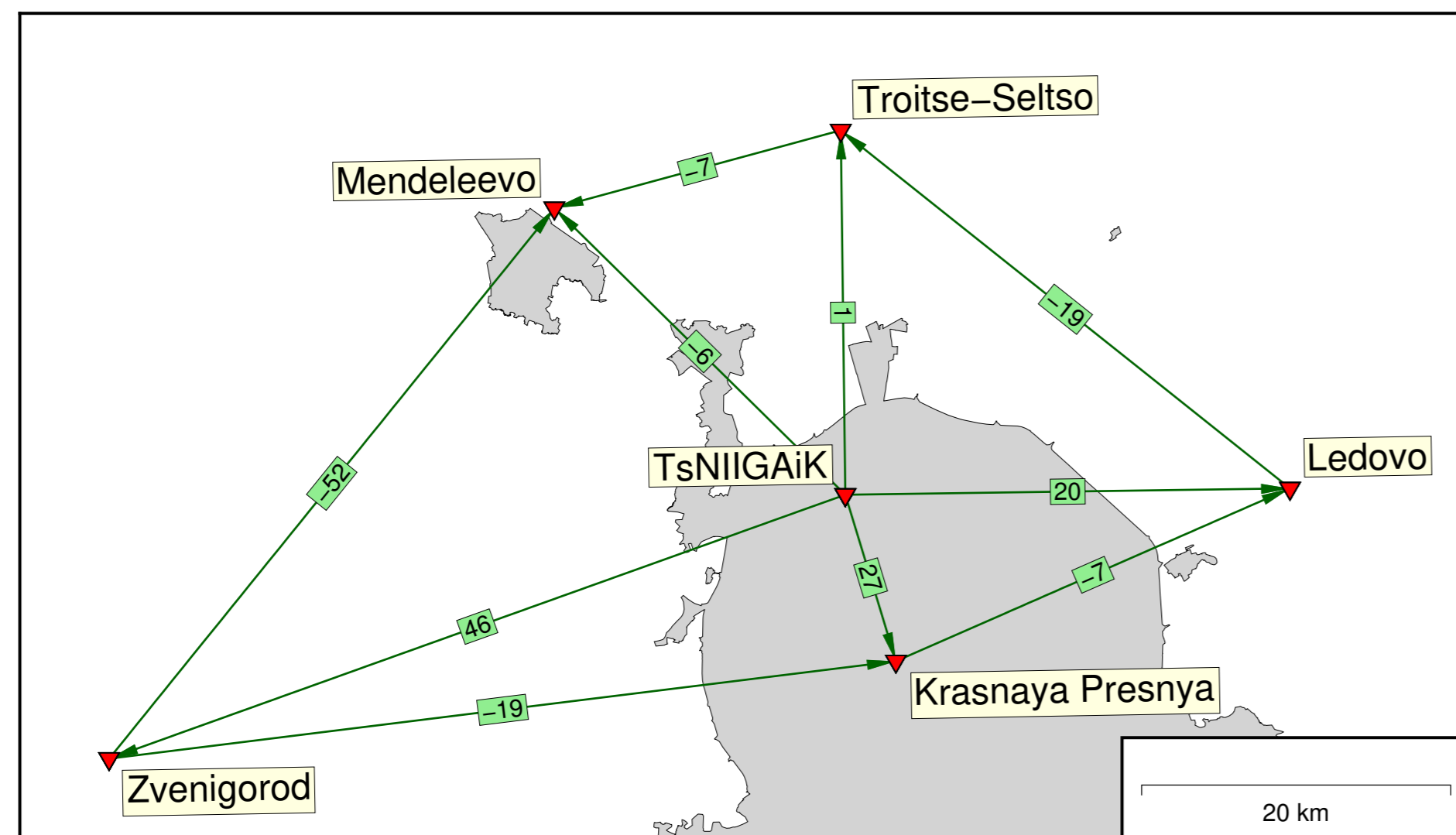


Figure 1: Moscow gravity network

The absolute gravity measurements at TsNIIGAIK and Zvenigorod were performed by FG5x #221 (Finnish Geospatial Research Institute) in 2013 and gravity values there are known w.r.t. ICAG2013 in Walferdange (Luxembourg).

The relative gravity measurements were planned so that each point was connected to the nearest three neighbors. There are 10 lines in the network.

2. Instruments and measurements

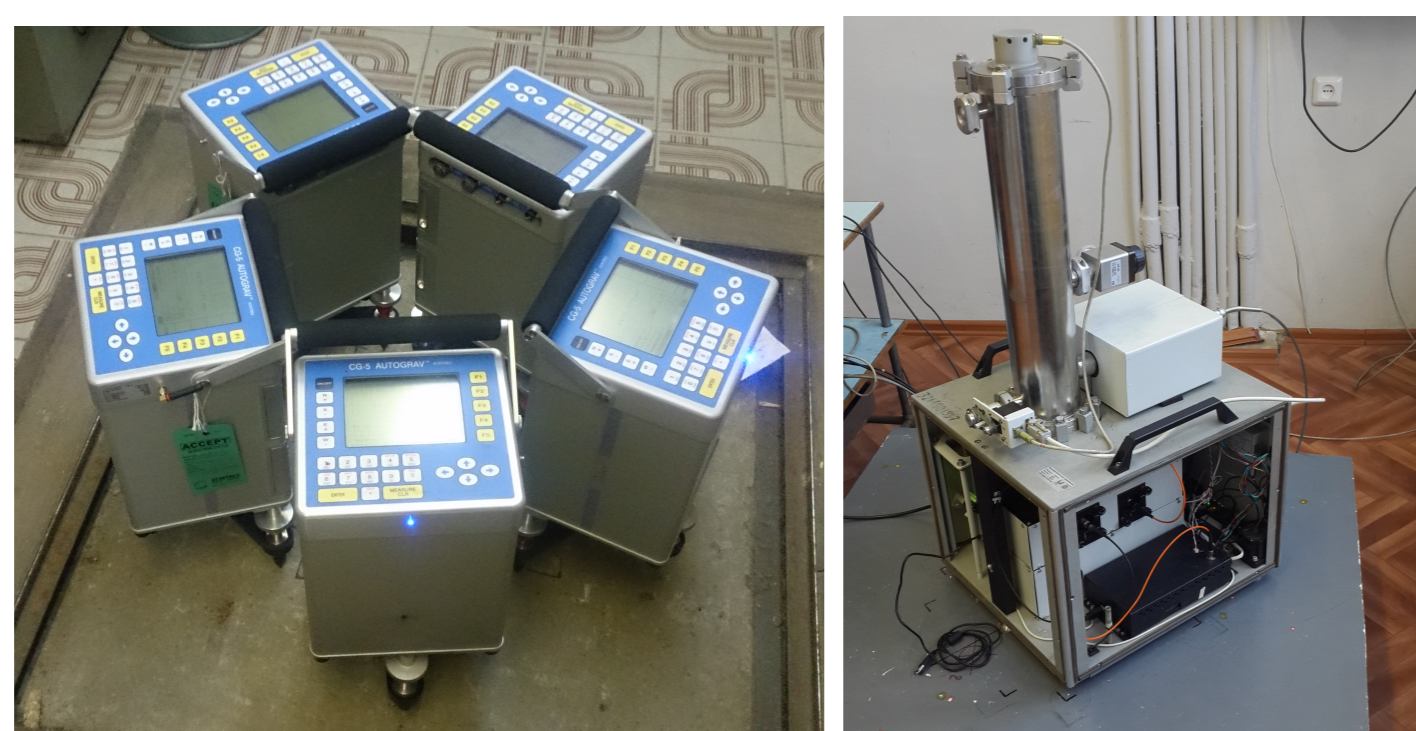


Figure 2: All CG-5 gravimeters (left) and absolute gravimeter GBL-M (right)

2.1 Absolute gravity measurements

The absolute gravity measurements were made with GBL-M #001 and #003 field ballistic gravimeters[3] (see Fig.2). Both gravimeters did not participate in RFCAG2013 and have no correction w.r.t. ICAG2013. The measurements were performed at three points with each gravimeter with overlaps (see table below).

S/N	Stations
GBL-M #001	TsNIIGAIK, Krasnaya Presnya, Mendeleevo
GBL-M #003	TsNIIGAIK, Krasnaya Presnya, Ledovo

All processing methods of the absolute gravity measurements were standard, except:

- no self-attraction and diffraction corrections were applied,
- Atlantida3.1 2014[2] was used to calculate tide correction.

2.2 Relative gravity measurements

The relative gravity measurements campaign with the five Scintrex CG-5

- #41262, 41265, 40443 (of TsNIIGAIK) and
- #41077, 4173 (of MIIGAIK)

spring gravimeters took place in March–May 2015 at all stations of the network for the first time.

Here are some highlights:

- difference method (from two to four runs per line);
- 30 – 60 minutes of measurements per station,
- thus no more than one line per day;
- very careful transportation in the hands of the operators to minimize the errors due to tilts, shocks, weather conditions etc.;

3. Data processing

All measurements were processed and adjusted with the newly and actively developed gravity processing software (not public yet) in Python programming language.

3.1 Vertical gravity gradients

The gravity changes above the mark were approximated by second degree polynomial (see Table. 2) as discussed in [1], unadjusted measurements at three or four vertical levels were used as input data.

Table 2: Polynomial approximation results: a and σ_a in μGal , b and σ_b in $\mu\text{Gal m}^{-1}$

Station	a	b	σ_a	σ_b	σ_{ab}
TsNIIGAIK	-349.59	15.59	3.50	2.48	-8.49
Zvenigorod	-321.86	4.00	4.20	2.93	-12.13
Krasnaya Presnya	-297.49	3.34	6.03	4.20	-24.82
Ledovo	-320.91	7.83	6.06	4.29	-25.50
Troitse-Seltso	-355.84	12.44	4.89	3.27	-15.56
Mendeleevo	-255.04	-3.43	8.69	5.41	-46.24

3.2 Network adjustment

The least-squares adjustment solutions were computed for three main cases:

- RG+ICAG2013: relative measurements adjusted with fixed absolute values at TsNIIGAIK and Zvenigorod;
- RG: relative-only (two scale-factors are taken as fixed);
- RG+AG2015: relative measurements adjusted with all absolute values from GBL-M gravity meters;

Absolute gravity values and gravity differences (48 ties in total) were used as input data.

The reference height of the adjustments is 0.265 m (mean height of the CG-5).

4. Adjustment results

4.1 Scale factors

Three different solutions give us three different scale factors for each CG-5 gravimeter (see Table.3).

In the relative-only adjustment the linear scale factors of the #41262 and #41077 gravimeters were taken as fixed as they are the closest to the absolute values.

Table 3: Linear scales and MSE of the CG-5s from different solutions

s/n	RG+ICAG2013	RG	RG+AG2015
41262	0.99995 ± 0.00008	1.0 ± 0.0	0.99993 ± 0.00008
41077	0.99999 ± 0.00008	1.0 ± 0.0	0.99998 ± 0.00008
40443	1.00090 ± 0.00008	1.00093 ± 0.00005	1.00088 ± 0.00008
41265	0.99961 ± 0.00008	0.99964 ± 0.00006	0.99960 ± 0.00009
41073	1.00105 ± 0.00008	1.00108 ± 0.00005	1.00104 ± 0.00008

The differences between solutions are no more than 7×10^{-5} and within 1σ interval.

4.2 Gravity values

The main results of the adjustment is gravity (see Table.4). It can be seen, that the differences between solutions are small. All systematic (mean) values are mainly here because of offset of the AG (see next section).

Table 4: Gravity values from the different solutions and their differences (indexes as in Section 3.2)

Station	(1) / mGal	(2) / mGal	(3) / mGal	1-2 / μGal	1-3 / μGal	2-3 / μGal
TsNIIGAIK	70.8290	70.8290	70.8267	0.0	2.3	2.3
Zvenigorod	25.0556	25.0541	25.0538	1.5	1.8	0.3
Krasnaya Presnya	44.3348	44.3339	44.3327	0.9	2.1	1.2
Ledovo	51.2207	51.2201	51.2184	0.6	2.3	1.7
Troitse-Seltso	70.2267	70.2267	70.2242	0.0	2.5	2.5
Mendeleevo	77.1064	77.1065	77.1035	-0.1	2.9	3.0
Mean				0.5	2.3	1.8
RMS				± 0.6	± 0.4	± 1.0

The column two in the table gives us the gravity values w.r.t. ICAG2013 through FG5x #221 and relative measurements.

4.3 Offset of the GBL-Ms

The offset values (see Table.5) for the GBL-M #001 and #003 are calculated from RG+ICAG2013 solution.

Table 5: Offset of the GBL-M gravimeters from RG+ICAG2013 adjustment

Meter	N	Offset / μGal
GBL-M #001	3	-1.2 ± 1.4
GBL-M #003	3	0.3 ± 3.1

It is interesting how small offsets are and how close they are to GBL-M #002 which participated in RFCAG2013. We can think about this values as of the offset from ICAG2013 reference value, but uncertainty propagation analysis needs to be improved.

Conclusions

- linear scale factors, gravity and offset of the AG were calculated from three different solutions;
- gravity in the Moscow gravity network values and offsets of the GBL-M #001 and #003 are known w.r.t. ICAG2013;

References

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