CALIBRATION OF SPRING GRAVIMETER ET-26 USING ABSOLUTE GRAVITY MEASUREMENTS

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1. INTRODUCTION

The tidal measurements at the Astro-Geodetic Observatory in Jozefoslaw began in 1993 with LaCoste&Romberg G model. Nowadays the Observatory is equipped with two gravimeters: the ET which is the most precise spring gravimeter and D model. The use of results depends on correct determination of the scale of tidal records which should have relatively high accuracy. The most frequently used method for calibration of tidal gravimeters with more or less regular drift is comparison to the absolute measurements. The repeated absolute gravity measurements with the FG5 No. 230 gravimeter at the Observatory in Jozefoslaw were used for computing calibration factors of the tidal gravimeters using least-squares fitting. The scales of the tidal gravimeters were determined from 8 2-day absolute campaigns performed between October 2006 and May 2007 with the accuracy of about 10%.

2. DATA

The data concerns observations collected between October 2006 and May 2007. Eight independent absolute gravity determinations were taken into account.

Table 1. Absolute data statistics.

No.	Date	Numbers of series
1	14.10.2006	24
2	11.11.2006	28
3	02.12.2006	14
4	07.01.2007	12
5	04.02.2007	13
6	03.03.2007	27
7	01.04.2007	13
8	05.05.2007	25

Each series consists of 100 drops, that means single determination of the gravity. The following figures present data collected during first calibration session in October 2006.

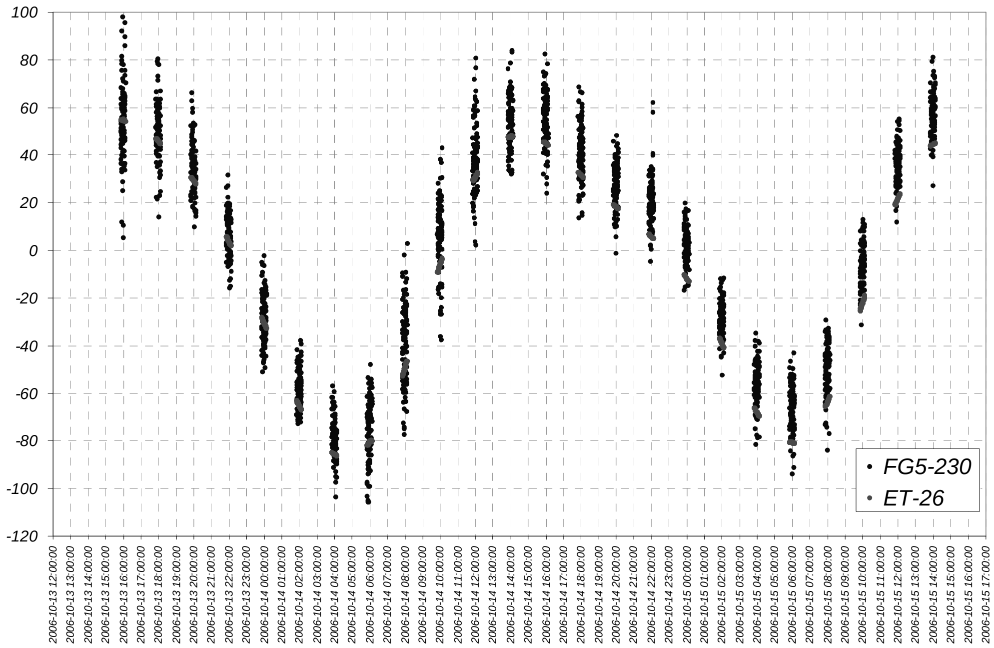

Fig. 1. Absolute and relative (ET-26) gravity data [nm/s^2].

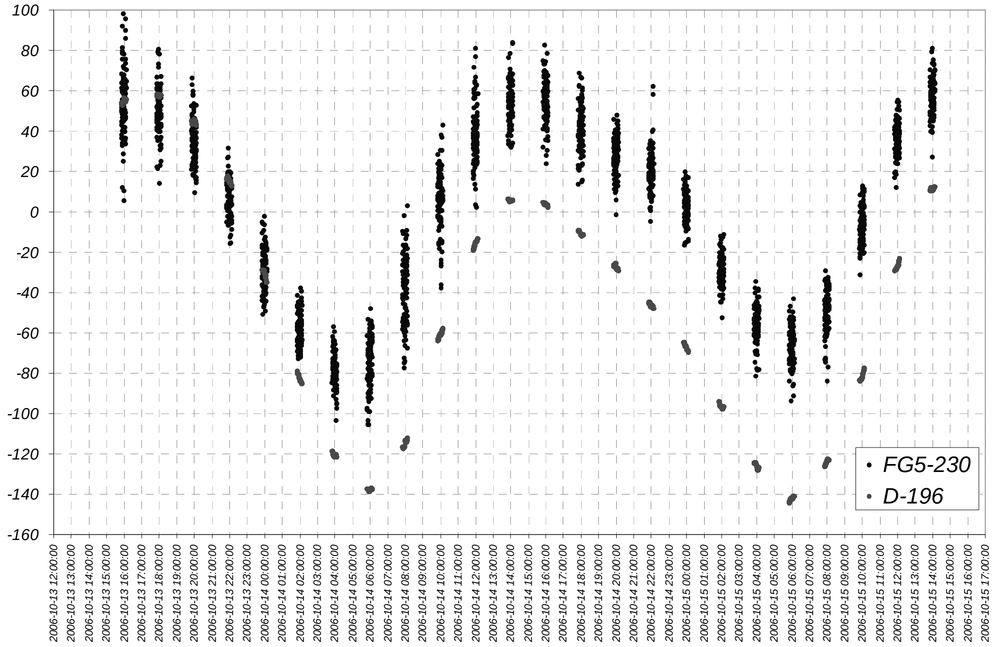

Fig. 2. Absolute and relative (D-196) gravity data [nm/s^2].

3. CALIBRATION

First of all we have to take a look at the particular series. The following chart presents observations collected by absolute gravimeter (100 drops) with standard deviations and ET-26 (standard deviation of relative determinations is much smaller – about 4 nm/s^2 – and not seen at the picture).

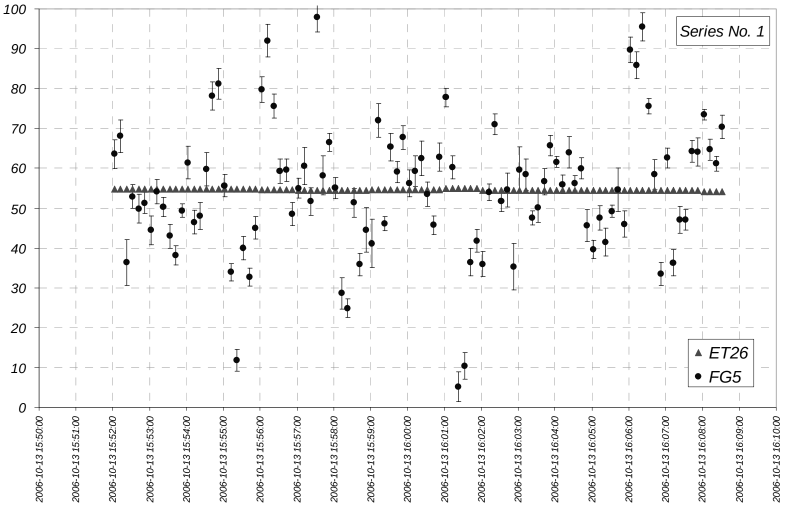

Fig. 3. Comparison between absolute and relative data in one series (100 drops) – [nm/s^2].

This chart illustrates first problem which occurred during calibration. The observations are different by means of accuracy and it is difficult to be compared. Absolute determinations are less precise and much more scattered. Relative determinations are more stable. The same situations appears in each series. It was assumed that mean value (after removing outliers using 3σ criterion) describes gravity for mean time of observation. The next chart presents observations after averaging in particular series.

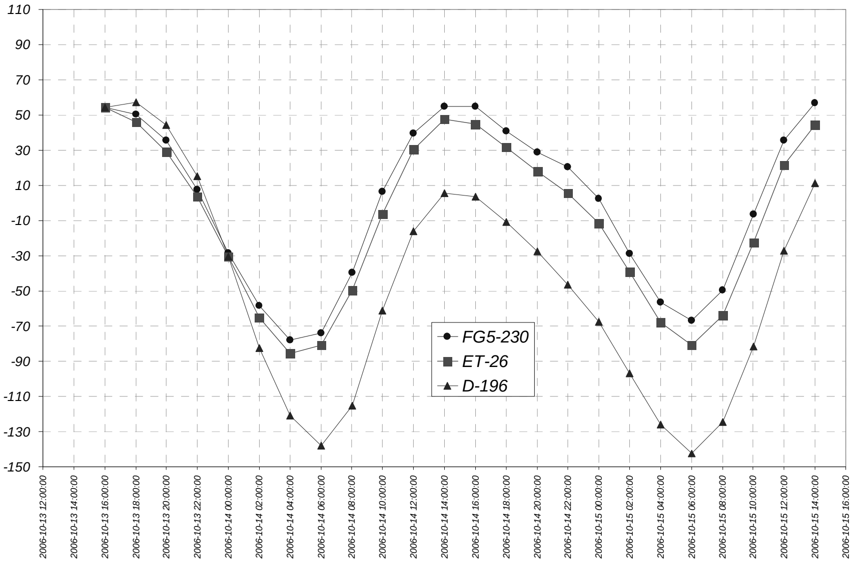

Fig. 4. Comparison between absolute and relative data in one series after averaging – [nm/s^2].

Next problem that is clearly seen is the existence of a kind of the drift between particular observations. Relative gravimeters always have drift but absolute instrument should be driftless. The easiest method for the drift determination is subtracting from observations theoretical tides and approximation using straight line. The following chart presents gravity determination together with the theotide calculated using Eterna 3.4 (Wenzel, 1996) package and HW95 tidal potential catalogue:

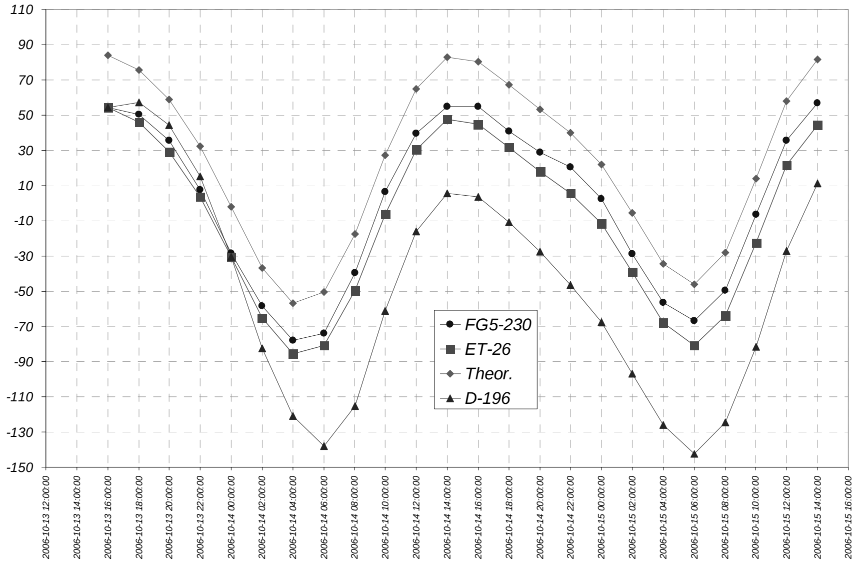

Fig. 5. Averaged gravimetric data with theotide – [nm/s^2].

and differences with linear approximation:

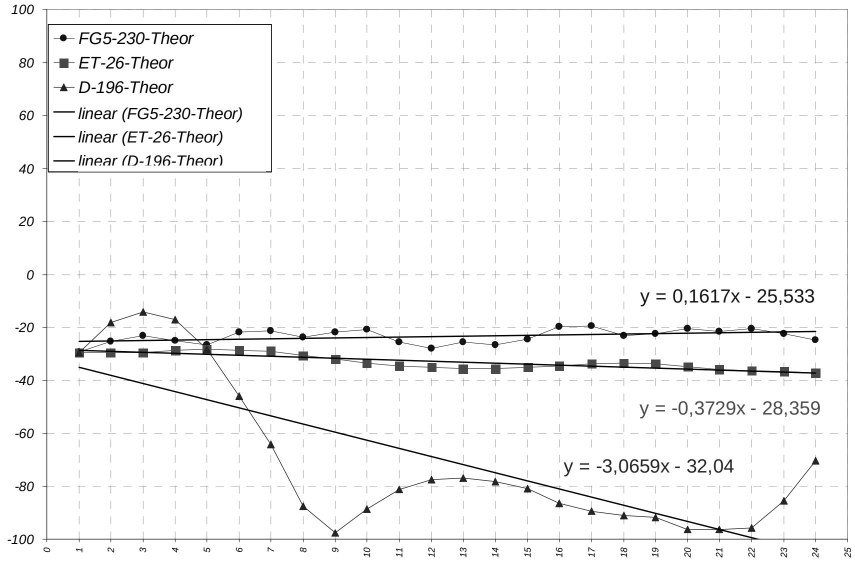

Fig. 6. Linear approximations – [nm/s^2].

After that the observations were restored to their original values using theoretical tides:

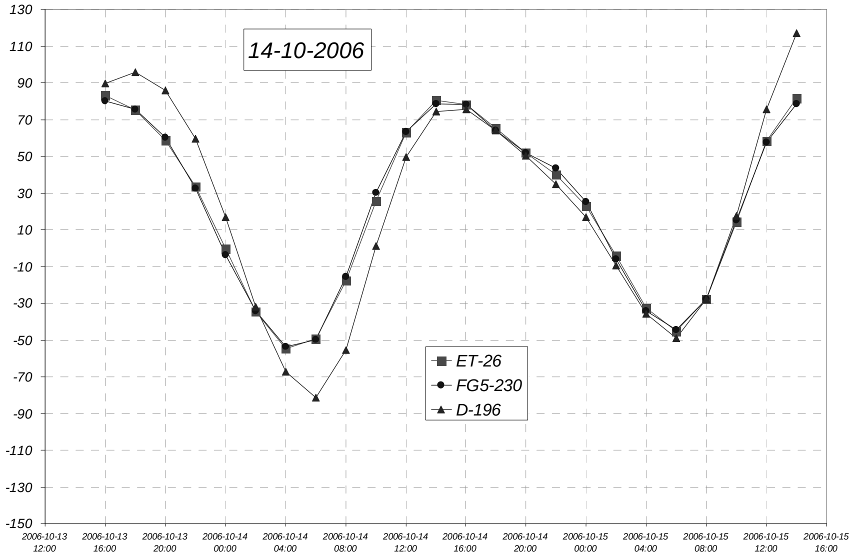

Fig. 7. Gravimetric data after drift elimination – [nm/s^2].

From the charts in figures 6 and 7 arise that constant factor of ET-26 gravimeter is determined almost correctly but the factor of D-196 not. Besides we can conclude that in D-196 observations there exists a kind of short-term linear drift, rather hard to eliminate using accessible methods.

4. PROCEDURE

To characterize properly relations between two curves describing the same phenomenon we have to implement two parameters: scale coefficient *k* and shift *s*. Then the relation could be written as follows:

$$a = k \cdot r + s \qquad (1)$$

where *a* and *r* are the observations made by absolute and relative gravimeters respectively.
The correction equation v would be by the following:

$$v = r \cdot k + s - a \qquad (2)$$

and then the system of the equation corrections is created:

$$R \cdot X - A = 0 \qquad (3)$$

where:
***R* - matrix of coefficients at unknowns;**
***A* - matrix of free terms;**
***X* - matrix of unknowns.**

Now we impose least square condition [*vv*]=min and we obtain:

$$\left(R \cdot R^T\right) \cdot X - R \cdot A^T = 0 \tag{4}$$

We calculate unknowns by the conversion:

$$X = \left(R \cdot A^T\right) \cdot \left(R \cdot R^T\right)^{-1} \tag{5}$$

Furthermore for each gravimeter standard deviations is determined:

$$m_0 = \sqrt{\frac{[vv]}{n}} \tag{6}$$

and errors m_k and m_s of the individual parameters.

5. RESULTS

Table 1. The results of the calibration of ET-26 gravimeter.

Date	k	m_k	s	m_s	m_0
2006-10-14	0,99063	0,13104	0,22155	0,99978	2,08869
2006-11-11	1,00274	0,09051	-0,04361	0,67684	1,51951
2006-12-02	1,00501	0,21204	0,19057	2,01968	3,68603
2007-01-07	0,98974	0,14963	0,26180	1,20420	2,12461
2007-02-04	1,00126	0,15549	-0,00961	1,30204	2,24868
2007-03-03	0,99760	0,19142	0,07186	1,53058	3,18699
2007-04-01	1,01391	0,27308	-0,69567	2,23100	3,59218
2007-05-05	1,00379	0,09635	-0,06936	0,81179	1,78250

Table 2. The results of the calibration of D-196 gravimeter.

Date	k	m_k	s	m_s	m_0
2006-10-14	0,77693	0,81107	5,25492	6,60012	14,03255
2006-11-11	0,49491	1,14507	2,33689	8,95726	19,16803
2006-12-02	1,70339	1,12711	-25,50761	9,70442	16,24105
2007-01-07	1,15458	1,60478	-3,94639	12,15223	20,88804
2007-02-04	2,10039	0,83518	-35,65612	6,96229	9,96981
2007-03-03	-	-	-	-	-
2007-04-01	1,70103	1,59154	-27,29255	14,95999	19,05920
2007-05-05	1,20426	1,46838	-6,43212	11,52691	24,65291

Finally the calibration factors were determined as follows:

ET-26: 1.00059 +/-0.007911
D-196: 1.30507 +/-0.565108

6. CONCLUSIONS

In present, the most precise tidal gravimetric measurements are collected using superconducting gravimeters, but spring gravimeters due to their availability are still used at many tidal stations. The usage of them is mostly limited by the constant factors determination.

ACKNOWLEDGMENTS

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REFERENCES

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