Calibration of relative spring gravimeters with the use of the A10 absolute gravimeter

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Abstract
Relative spring gravimeters require periodic scale factor determination in order to assure the quality of gravity measurements as well as to check whether their performance is acceptable for gravimetric purposes. From gravity control measurements, small scale gradient determinations to total measurements, different accuracy of the scale factor determination is required. Calibration of relative gravimeters with the use of absolute gravimeters, usually FGs, is a common practice. An attempt of using the A10 absolute gravimeter for this purpose is described. The Institute of Geodesy and Cartography (IGiK) possesses three LaCoste&Romberg (LCR) model G gravimeters equipped with a feedback system LRF6-300, and one A10-020 absolute gravimeter of Micro-g. For the last 20 years LCR gravimeters owned by IGiK were calibrated only on the well maintained Polish gravity calibration baselines. Starting from the beginning of 2012, one of the relative gravimeters is used in the Bonnere Goeotdis-Geophysikalischer Observatorium as a total gravimeter. Test measurements including simultaneous gravity recordings were performed with the use of the A10 and three LCR G gravimeters. The least squares adjustment gives the accuracy of the scale factor determination at the level of 1%. Ten applications of the determined scale factor are discussed. One consists gravimetric total recordings, and the other one - small scale gradient determinations. Results of calibration with the use of the A10 were compared with the scale factor obtained from the survey at the gravimetric calibration baseline. Additionally the performance of the A10 gravimeter is discussed.

1. Instrumentation

The A10 absolute gravimeter (Fig. 1) serial No 020 had been used for calibration of LaCoste&Romberg (LCR) gravimeters. The gravimeter is manufactured by Micro-g Inc. It is designed as a two-separate laser (M-L, He-Ne) laser systems for gravity determinations. Average of gravity determinations of each mode provides the final absolute gravity value. The gravimeter is designed to provide gravity data in an efficient way allowing to execute single drops with maximum 1Hz frequency (500µGal, 2008a). Data acquisition was performed with standard Micro-g software (uMicro-g), a software developed by Micro-g. Relative gravimeters used in the calibration were three LCR model G gravimeters (serial No 1012, 1036, 1084) equipped with LRF6-300 feedback system (Fig. 1) which allows data acquisition with 1Hz time resolution and one micropul readout resolution. All three gravimeters send data via bluetooth to a computer or a PDA-based unit (i, and I, Meter Service, 2009).

One of the relative gravimeters, i.e. LCR G1036 is currently used in the Bonnere Goeotdis-Geophysikalischer Observatorium as a constantly recording total gravimeter. It provides constant periodical calibration; the gravimeter was calibrated at IGiK in June 2012. In 2011 all A10 gravimeters and in 2012 two LCR gravimeters were calibrated on the Central Gravimetric Calibration Baseline in Poland.

2. The measurements

Three calibrations with the use of the A10-020 had been performed. All of them with slightly different measurement settings as presented in Table 1.

Table 1. A10-020 measurement settings for performed calibration

<table>
<thead>
<tr>
<th>Date</th>
<th>No. sets per session</th>
<th>Sequence interval</th>
<th>No. drops per set</th>
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Raw LCR results had been averaged over 2 minutes interval required for the A10-020 to perform a single set. Metrological parameters had been applied to LCR measurements to verify the expected low noise performance and improve the stability of used A10 data.

Figure 2 presents raw results of A10-020 and three LCR gravimeters from the calibration performed in June of 2012. Strong LCR drift is clearly visible for all of the gravimeters. Compared with the A10 results the LCR drift had been eliminated with second degree polynomial adjustment results shown in Figure 3. Pearson linear correlation coefficient for each gravimeter is given in the left top corner box. Coefficients for all gravimeters provide a high value with a slightly stronger correlation for the LCR G1036 gravimeter. The calibration presented more widely in the poster was performed between 22 and 25 June of 2012. During the measurement period of the calibration variation of the wind, humidity, temperature, and other effects affected the readings of the A10-020 and each of the relative spring gravimeters. Figure 5 presents the observed standard deviation for the LCR G1036 gravimeter. The standard deviation of the measurement is about 1µGal which corresponds to a sensitivity of 0.9991. This value is consistent with the scale factor value -0.9953 obtained in the poster presentation.

3. Adjustment results

Least squares adjustment had been applied to the data with removed drift. A simple linear model was used:

\[ y = A + k \cdot x \]

- \( A \) - absolute gravimeter value
- \( k \) - relative gravimeter value
- \( x \) - shift

As the A10-020 provides data in two separate modes, adjustment procedures had been applied to both with the use of the red and blue mode, as well as single average values from the modes. Adjustments performed at calibration incorporate weights which are proportional to the inverse error of set determination by the A10-020 (Fig. 5). For the LCR gravimeters different results are obtained. Results of all calibrations (resulting from A10 red mode, blue mode and the average) are presented in Figure 6 for LCR G1012, G1036 and G1084. The graphs also include scale factor \( k \), values as determined on the gravimetric calibration baseline. Combined results are presented in Table 2.

Table 2. Scale factor \( k \) values determined with the A10-020 compared with baselines calibration

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<tr>
<th>Date</th>
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<th>Sequence interval</th>
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4. A10-020 performance

As shown in Figure 5 the A10-020 sensitivity corresponds with LCR noise recordings. Experience coming from these calibrations as well as other applications (Dykowski et al., 2012) prove that the A10-020 performance and gravity gradient measurements are better when typical acquisition settings are set. As a result the Calibration of relative gravimeters G1012 and G1084 with A10-020 average red/blue mode set values during calibration performed in June 2012.

Figure 6 presents stabilization of the scale factor corresponding with the number of combined sets used in the adjustment. Data presented for the last calibration – from June of 2012. Each of the relative gravimeters has been adjusted using the characteristics of the scale factor calibration. Visual inspection of Figure 7 shows that a possible signal was used for the adjustment. As all of the relative gravimeters the A10-020 was performed as a baseline. Differences between A10 and LCR gravimeters after removing drift

\[ \Delta g = g_{A10} - g_{LCR} \]

are in very good agreement with each other. The error of determination finally reaches a value visibly lower than 1%.

Figure 7. Scale factor stabizlation as a function of number of sets

5. Discussion/Conclusion

Results of the calibration with the use of the A10-020 provide scale factors with an accuracy close to 1%. This range of accuracy is also achieved by other authors referring to the calibration of spring gravimeters with the use of absolute values (Bozusz, 2006, Rajner, 2010). As a result the calibration of small scale measurements improve the accuracy of determinations.

The A10-020 calibration was performed with the use of several triples (Dykowski, 2011). It is, therefore, crucial to verify and control their scale factors. Current knowledge on the range of vertical gravity gradient determinations in Poland gives values from -2.2 (Sas-Uhrynowski, 2002) to -4.9 µGal/cm (Sas, 2009). At typical range of current vertical gradient determinations (Fig. 9), the accuracy of determination would be less than 1%. In the case of the A10-020, the error of determination significantly changes from 2 to 5µGal which is close to the A10-020 measurement error.

Acknowledgments
The authors wish to thank Prof. J. Kryński and Dr. M. Rajner for useful comments concerning the poster preparation.

References