Improved processing method of UEGN-2002 gravity network measurements in Hungary

L. Völgyesi, L. Földváry
Department of Geodesy and Surveying, Budapest University of Technology and Economics; Research Group of Physical Geodesy and Geodynamics of the Hungarian Academy of Sciences, H-1521 Budapest, Hungary.
G. Csapó

Abstract. A new method and software has been made and tested in the Hungarian part of the UEGN-2002 network. Making a suitable base gravity network and providing proper data for UEGN-2002 has required some experimental measurements and many important investigations. In case of precise gravity measurements the determination of the vertical gradient’s real value is necessary. Using the real or normal value of vertical gradients may give 6-10 µGal differences of height reductions depending on the reference height of the instruments. Taking into account the periodical errors of LCR gravimeter’s reading device is very important; neglecting the periodical errors may give 25-30 µGal errors of $\Delta g$ between measured points depending on the instrument (in case of our instruments LCR 963 and 1919 it was found to be below 2 µGal). We have found that the accuracy of the parameter estimation increases with fewer periods estimated. We suggest to always use a full parameter set for the estimation of the periodical correction. Based on our investigations the reliability of the MGH-2000’s adjusted data is significantly better, than the reliability of the European network’s one (probably because of the different reliabilities of the different European countries’ gravity data). According to our plans, after the final adjustment of UEGN-2002 we are going to readjust the Hungarian MGH-2000 taking into account the adjusted g values of UEGN-2002 referring to Hungary as constraints of a fixed network.

Keywords. Gravimeters, gravity measurements, gravity networks, vertical gradient, periodical errors, corrections of measurements, adjustment

1 Introduction

The International Union of Geodesy and Geophysics (IUGG) has long been planning to set up a unified scale and datum gravimetric network which could be applicable in the whole continent of Europe. Its conditions have been established when several countries have got absolute gravimeters, providing unified scale in accordance with the current accuracy specifications. At the same time the need for increasing the accuracy of global geodetic reference systems, and for solving several geodynamic and geotectonic problems, have brought about the realisation of this objective as a daily routine. Among others this purpose was served by the establishment of Unified European Gravity Net (UEGN-93) by 11 countries (Boedecker, 1993). Later further countries such as Hungary have been joined to UEGN and completed some necessary works (making new absolute points and performing common measurements on the neighbouring countries’ network) for the joining. Unfortunately significant inhomogeneities of the UEGN-93 point distribution can be seen, investigating the networks of the different UEGN countries. As far as we know there is no country which has transformed its own network to the UEGN datum up to now. However this is an important problem and according to our plans after the final adjustment of UEGN-2002 we are going to readjust the Hungarian MGH-2000 taking into account the adjusted g values of UEGN-2002 referring to Hungary as constraints of a fixed network.

2 The former Hungarian gravity networks

We provide an overview of processing and adjustment methods that have been applied for the gravimetric network in Hungary from the beginning of the fifties up to now. In former times to make use of complex equations was not feasible according to the computational capacity of the time, so many factors have been neglected, e.g. instrument drift.

For the first time, the Hungarian gravimetry network has been determined in the 1950s (referred as MGH-50). Both the processing and the adjustment have been done manually; solving this problem was a definitely time consuming procedure. In the eighties due to the development of computers, processing of data with much larger set of unknowns be-
came executable. The registration of the observations, the processing method and also the adjustment became much more easily feasible, providing more space for optimization of the solution, e.g. the parameterisation of the processing sequence could be done in different manners (a priori and a posteriori as well), or tests could be performed for an optimal adjustment method.

Previously the memory limits of computers allowed solving for some hundred unknowns in a short duration. Nevertheless, in order to be able to handle more unknowns in a more flexible way and to consider more effects than before (e.g. changes in water table, periodical errors of the data registration), the development of an up-to-date software became necessary. A new method and software has been made and tested in the Hungarian part of the UEGN-2002 network and the accuracy of the adjusted gravity network has been improved.

Hungary’s first gravity network (MGH-50) covering the entire territory of the country was established by the Loránd Eötvös Geophysical Institute (ELGI) during the early 1950s. The measurements were carried out by a Heiland GSC-3 astatic gravimeter. Both the processing and the adjustment of these measurements have been carried out manually in 1954. This network was containing 16 first order and 493 second order points. Description of measurements, processing’s and adjustment’s method and the results can be found in (Renner and Szilárd 1959). Constraints of the second order network adjustment were the adjusted g values of the first order network points. MGH-50 gravity network was adjusted in the Potsdam Gravity System. It is interesting to mention that a correction of magnetic azimuth was applied here for the first time; this type of correction was applied nowhere else before. At the same time the height correction was not applied here. According to our estimations considering that all measurements were made on a special tripod, omitting the height corrections may cause about 5-15 \( \mu \text{Gal} \) errors of adjusted g values.

As a result of industrial and infrastructural developments during the 1960-70s, most of the base points established mainly along national roads were beginning to deteriorate or simply became unsuitable for their original purposes. This was the main reason why a new gravity network had been established during the 1980-88s. One part of network measurements was performed in international cooperation (Csapó et al, 1994), and 8 Sharpe, 4 Worden and 1 LCR-G gravimeters were applied in the measurements. Before the adjustment process a lot of different investigations were performed (Csapó, Sárhidai 1990a) and the results were applied to our newest gravity network. The network has been adjusted as a fixed one by LSQ method, this was the common adjustment of the first and the second order network. The constraints were the \( g \) values of the 5 absolute points measured by the GABL absolute gravimeter. A lot of different adjustment version was investigated, but each version of adjustment used the measured \( \Delta g \) values between points as an independent measurement data (Csapó, Sárhidai 1990b). The error of unit weight of the adjusted network is \( \mu_{0} = \pm 16 \mu \text{Gal} \), the errors of adjusted values are \( \pm 2-9 \mu \text{Gal} \) for the 408 points (1 \( \mu \text{Gal} = 10^{-8} \text{ms}^2 \)).

3 Necessity of determination of a new Hungarian gravity network

The establishment of the newest gravity network MGH-2000 in Hungary and the necessity of a new processing of the measurements are essential due to several reasons (Csapó, Völgyesi, 2001). First of all, several new absolute measurements have been performed in the country. Moreover the points of Hungarian part of UEGN-2002 are taken out from the points of the new MGH-2000 network demanding an increased need in accuracy.

Making a suitable base gravity network and providing proper data for UEGN-2002 has required some experimental measurements and many important investigations. In what follows these investigations and results are presented.

4 Influence of local vertical gradients on the values of \( \Delta g \) between points

Generally only the normal value of vertical gradient (0.3086 mGal/m) is used for height reduction of gravity measurements instead of the real value. During last years we have determined the real value of vertical gradients at different points and found a difference 20-25% between the real and the normal values (Csapó, Völgyesi, 2004). In Table 1 values of measured vertical gradients can be seen as examples in some points in Hungary. In this table \( \varphi \) and \( \lambda \) denote ellipsoidal coordinates, \( H \) is the height of the point and \( V \) is the vertical gradient.

In case of precise gravity measurements (e.g. measurements on a calibration base line or measurements on special polygons for investigations of local variations of gravity) the use of observed vertical gradient’s real value is necessary. Using the observed or normal value of vertical gradients may give 6-10 \( \mu \text{Gal} \) differences of height reductions depending on the reference height of an instrument.