Retraction

Retraction: Bayesian estimation of scale factor for CG-5 relative gravimeter (IOP Conf. Ser.: Earth Environ. Sci. 734 012037)

Qiuyue Zheng¹, Dong Liu¹,*, Linhai Wang², Jiangpei Huang¹ and Qinghua Wang¹

1 Yunnan Earthquake Agency, Kunming 650224, Yunnan, China
2 Institute of Geophysics, China Earthquake Administration, Beijing 100081, China

Published 10 June 2021

This article has been retracted at the authors request, for the following reasons:
• The work was submitted without the approval of the one of the co-authors, Linhai Wang.
• The original gravity data used in the paper has been found incorrect through repeated verification recently, which is leading to erroneous conclusions.
• The theoretical method used needs further development before it is ready for publication.

All co-authors agree to this retraction.
Retraction published: 10 June 2021
Bayesian estimation of scale factor for CG-5 relative gravimeter

Qiuyue Zheng¹, Dong Liu*, Linhai Wang², Jianpei Huang¹, and Qinghua Wang¹

¹Yunnan Earthquake Agency, Kunming 650224, Yunnan, China
²Institute of Geophysics, China Earthquake Administration, Beijing 100081, China

* Corresponding author: doumo@whu.edu.cn

Abstract. The terrestrial time-variable microgravity survey is an important means to monitor geodynamic processes underground. The Scintrex CG-5 relative gravimeter, which is the mainstream instrument for terrestrial relative gravity measurement at present, its scale factor (SF) is an important factor affecting the quality of the observation data. Unlike the conventional gravity adjustment procedure, this study takes account of the nonlinear drift rate of the CG-5 gravimeter, depending on the known absolute gravity (AG) in the network, and the scale factor is considered as one of the hyper-parameters to be estimated by means of Akaike’s Bayesian information Criterion (ABIC). In order to quantify the errors caused by the bias of scale factor, we applied this new approach to process actual gravity survey campaign data in Yunnan gravity network from 2018 to 2020, then analyzed the residuals of gravity differences (GD) between station pairs and the difference of GD between two relative gravimeters (CG5 #1169 and CG5 #1170). The cross-validation of the absolute gravity (AG) from the quasi-synchronous observation in the network is also used in the paper. It has shown that this new approach is effective to improve the accuracy of scale factor and adjustment results.

1. Introduction
The variation of terrestrial gravity field is the most basic and direct physical quantity of geodynamic characteristics under various environments which reflects the variation of the density of the earth medium. High precision of terrestrial time-variable microgravity signal which retrieved by means of the repeated measurements at the fixed stations in the surface with a regular time interval, is one of a common method in geophysical exploration and time-variable gravity field research, which includes absolute gravimetry and relative gravimetry. And the regional microgravity signal obtained from gravity network has been successfully used to study geoscience problems, including crustal deformation (Van Camp et al., 2016), groundwater change (Van Camp et al., 2006), Glacier mass change (Ophaug et al., 2016), mineral exploration (Hare et al., 2008), Volcanic study (Williams et al., 2008), and Earthquake research (Chen et al., 1979; Kuo et al., 1993; Imanishi et al., 2003; Zhu et al., 2010; Zhu et al., 2012; Chen et al., 2016; Chen et al., 2015).

In recent years, an expanded national network of crustal deformation monitoring, the Crustal Movement Observation Network of China (CMONOC) has been established, including 101 absolute gravimetric stations and 3500 relative gravimetric stations, and the relative gravimeter has been widely used. The repeated observations are carried out in fixed time interval (twice a year), which can obtain time-variable gravity signals in different spatio-temporal scales. Currently, even though relative gravimeter commonly used involves Lacoste-G, Burris, CG-5 and CG-6 spring gravimeter, the CG-5 gravimeter still plays an important role in the terrestrial gravity measurement. Its sensor is a non-static...
fusing quartz spring, and its accuracy is better than 5µGal (1µGal=1×10⁻⁸m/s²), the reading resolution is 1µGal (Lederer., 2009; SCINTREX L, 2012). Although the accuracy of the terrestrial relative gravity is high, the SNR (Signal noise ratio) is low and at a scale of a few tens of microgal. Therefore, higher requirements are put forward for high-precision observation and data processing of terrestrial time-variable gravity signals.

The drift of the CG-5 relative gravimeter is inevitable, which reaching up to 200µGal/day (Crossly et al., 2013). Especially for the campaign more than 24 hours, the drift rate is not linear. (chen et al., 2019). Moreover, the scale factor of the relative gravimeter changes slightly with time, which is an important factor affecting the adjustment results. At present, the long baseline calibration has been performed every 3-5 years. However, the long baseline calibration is money-consuming, and at the cost of time, and the current calibration period cannot meet the observation survey of twice a year in the survey area.

However, the calibration of scale factor with the nonlinear drift in the adjustment for relative gravimeter is rarely discussed. In this paper, the scale factor and drift rate are quantitatively analyzed based on Akaike’s Bayesian Information Criterion (ABIC) (Akaike et al., 1980), and the new Bayesian adjustment method used for relative gravity campaign data have been proposed by Chen et al. (2019). Considering the nonlinear changes of drift, the drift rate is assumed as smoothly, the noise and variance including the scale factor of the instruments are all regarded as hyper-parameters to be solved by the means of ABIC criterion. Finally, based on the regional time-variable microgravity data of Yunnan region from 2018 to 2020, the residual of gravity difference (GD) at adjacent two stations and mutual difference of GD between two gravimeters (CG5 #1169 and CG5 #1170) caused by the scale factor bias have been quantitatively analyzed, the cross-validation of the absolute gravity results from the quasi-synchronous observation in the network is also applied in the paper. The results of this study can effectively reduce the observation error caused by the nonlinear drift rate of the instrument, obtaining the accurate grid value coefficient of the instrument according to the measured data without long baseline calibration, and provide a reliable data basis for the study of gravity anomaly signals caused by medium migration.

2. Gravity network and structure

Yunnan is located in the southern section of the north-south seismic belt, which is closely affected by the strong collision between the Indian plate and the Eurasian plate, and has become one of the most intense and frequent areas of seismic activity in China. The background of tectonic activity in the region is complex and strong earthquakes occur frequently. The active Xianshuihe fault, Xiaojiang fault, Zemuhe fault, Anning river fault, Red river fault and Lancang river fault are scattered in this region.

Fig.1 The distribution of gravity network and geological structure in Yunnan area.
Since 2018, a complete regional survey network covering the main fault structures in the whole Yunnan area has been established (Fig. 1). The blue diamonds are the absolute gravimetric stations, the light blue square points are relative gravimetric stations (almost 245 stations), the blue line are observation segments (more than 256 in each period), the red points are the earthquake (M≥5.0) in recent 10 years, the yellow square points around the Yunnan area are the stations in neighboring provinces, and campaign time increased to more than 90 days each period. The gravity changes of two adjacent stations (GD) and absolute gravity (AG) values are shown in Fig. 2, the different colored dots in the center of each blue line represents different GD of the adjacent stations. The maximum of the GD is 305mGal (10^{-5}m/s^2), and the minimum is less than 100µGal. Distance between two adjacent stations is about several tens of kilometers, and road vehicles are used to travel between stations. In order to remove the influence of seasonal rainfall changes, the observation is accomplished semi-annually.

![Fig.2](image)

**Fig.2** The distribution of GD (gravity differences) values between two adjacent stations AG (absolute gravity) values in Yunnan area.

### 3. Bayesian adjustment method

Generally, more than two relative gravimeters are used in the campaign, and measurements contains redundant observations. While the classical network adjustment adopts the least-square-method to establish adjustment model then solve this problem, and the drift rate is considered as linear. However, the solution of the problem is attributed to an over determined system of equations practically, which leads to the non-uniqueness of the solution. In this study, the ABIC criterion has been adopted to optimize the solutions. Assuming the observation error, absolute gravity error and the drift error obey the normal distribution, then:

\[
\begin{align*}
A\tilde{x} + D\tilde{v} - \tilde{y} &\sim \text{Normal}(0, \sigma^2) \\
G\tilde{x} - \tilde{g} &\sim \text{Normal}(0, \sigma^2_g) \\
B\tilde{v} &\sim \text{Normal}(0, \sigma^2_b)
\end{align*}
\]

In which, $\tilde{x}$ is the gravity values at all stations, $\tilde{v}$ is the drift rate of all the gravimeters, $\tilde{y}$ is the vector of observed GD values, and $\tilde{g}$ is the observed absolute gravity values. The expression of them are as follows:

$\tilde{x} = [x_1, x_2, \ldots, x_p]^T$,  \hspace{1cm} $\tilde{v} = [v_1, v_2, \ldots, v_p]^T$
\[
\vec{y} = [\vec{y}_1, \vec{y}_2, \ldots, \vec{y}_n]^T, \quad \vec{g} = [\vec{g}_1, \vec{g}_2, \ldots, \vec{g}_n]^T.
\]

Here, \(\sigma^2\), \(\sigma_g^2\) and \(\sigma_b^2\) are the observed noise variance, absolute gravity variance and instrument drift rate variance respectively. \(A, D, G\) and \(B\) are the observation order matrix, observation time matrix, absolute point matrix and second order smooth matrix respectively, and \(P\) is the number of the gravimeter.

If \(S = \begin{bmatrix} A & D \\ G & 0 \end{bmatrix}\), \(X = \begin{bmatrix} \vec{x} \\ \vec{v} \end{bmatrix}\), \(Y = \begin{bmatrix} \vec{y} \\ \vec{g} \end{bmatrix}\), \(W = \begin{bmatrix} W & 0 \\ 0 & W_g \end{bmatrix}\) and \(\sigma^2, 0 \quad 0, \sigma_g^2, 0 \quad 0, \sigma_b^2\) then the expression can be written as:

\[
\begin{bmatrix} A & D \\ G & 0 \end{bmatrix} \begin{bmatrix} \vec{x} \\ \vec{v} \end{bmatrix} = \begin{bmatrix} \vec{y} \\ \vec{g} \end{bmatrix}
\]

(4)

And \(U(X) = (SX - Y)^T W (SX - Y)\), the observation GD is \(\vec{y} = \Delta y - \Delta T l - \Delta P \alpha - \Delta \beta\), \(\Delta y\) is the gravity reading of GD, \(l\) is the scale factor, \(\Delta T\) is the solid tidal of the GD, \(\alpha\) is the tidal factor, \(\Delta P\) is the gravitational load difference of atmospheric pressure, and \(\beta\) is pressure admittance coefficient.

The joint probability density distributions of relative gravimeter and absolute gravity observations with multiple instruments:

\[
L = \det(2\pi W)^{-1/2} \exp\left(-\frac{1}{2} (SX - Y)^T W (SX - Y)\right)
\]

(5)

Then the ABIC formula can be written as the equation (6), which balancing the model parameter complexity and the model's ability to describe the data set (i.e. the likelihood function) by calculating the minimum ABIC value,

\[
ABIC = -2 \text{maxlog}(L) + 2H
\]

(6)

\(H\) is the number of hyper-parameter, and \(H=3P\) in this study. By solving the maximum likelihood of the equations above, the optimized \(\vec{x}\) and \(\vec{v}\) can be estimated.

4. Bayesian estimation of actual data

The current gravity survey network in Yunnan Province cannot be finished in 24 hours, adopting two relative gravimeters CG5 #1169 and CG5 #1170 (written as #1169, #1170 in the next). In this paper, we employ the time-variable gravity field data of six consecutive periods from 2018 to 2020 in Yunnan. For simplicity, the different period of measurement are written as 2018C1, 2018C2, 2019C1, 2019C2, 2020C1, and 2020C2. The nonlinear drift characteristics of two relative gravimeters after Bayesian adjustment are obtained, then the scale factor has been calibrated by means of ABIC criterion.

4.1. Drift rate estimation of the two gravimeters

On the basis of 2020C2 gravity data Fig. 3a shows the fitting daily drift rate of the two gravimeters by means of Bayesian adjustment (an average drift rate is calculated every day, which is expressed as the drift rate change per hour). It is obviously that the drift rate of the two gravimeters varies asynchronously, among which the #1169 gravimeter is more sensitive to the variation of observation time, topography, air pressure and route, etc. And the drift rate shows nonlinear drift characteristics apparently, and the difference between the maximum and minimum values of change is approximately 10µGal/h, which means that the maximum drift of a day can differ up to 240µGal in one day, which is far exceeding the observation errors of the measurement.
Fig. 3c and 3d are the GD residuals of the Classical (CLS) and Bayesian (BAY) adjustment method from #1169 and #1170 respectively. Obviously, the GD residual of traditional adjustment appears non-stochastic signals, and the pattern of this changes is same as the drift rate of the instrument in Fig. 3a, especially to the gravimeter #1170. While the GD residual of Bayesian adjustment is basically a stochastic signal, with correlation with drift barely, which shows that errors caused by the nonlinear drift of the relative gravimeter can be removed by the means of Bayesian approach.

Then Fig. 3b indicates that the histogram of GD residuals from classical adjustment (CLS) and Bayesian adjustment (BAY), which can be concluded that the GD residual by means of Bayesian adjustment presents normal distribution basically, and the SD of the GD residual decreased from 7.0µGal to 6.3µGal.

Table 1 The comparison of original scale factor (SF) and optimized scale factor (SF) of the six period from 2018 to 2020.

| Time of the survey | SF of #1169 | SF of #1170 | Difference (ppm) | SF of #1169 | SF of #1170 | Difference (ppm) |
|-------------------|-------------|-------------|-----------------|-------------|-------------|-----------------|
| 2018C1            | 1.000253    | 0.999956    | -297            | 1.000066    | 0.999752    | -314            |
| 2018C2            | 1.000292    | 0.999991    | -301            | 1.000066    | 0.999738    | -328            |
| 2019C1            | 1.000089    | 1.000126    | +37             | 0.999928    | 0.999899    | -29             |
| 2019C2            | 1.000152    | 1.000097    | -55             | 0.999865    | 0.999835    | -30             |
| 2020C1            | 1.000233    | 1.000094    | -139            | 0.999950    | 0.999829    | -121            |
| 2020C2            | 1.000335    | 1.000147    | -188            | 0.999987    | 0.999813    | -174            |

4.2. The estimation of scale factor

The scale factor of the relative factor is changing by the time (Onizawa et al., 2019; Wang et al., 2020), and the inaccurate scale factor will lead to systematic errors between the two instruments, especially in the large gravity difference (GD) between the two adjacent stations.

In Yunnan, the calibration of the scale factor has been accomplished in the long baseline, at the beginning of 2018, while the scale factor is far from meeting the current measurement requirements. Then, depending on the quasi-synchronous absolute gravity in the network, we applied Bayesian
approach to estimate the scale factor. Since the time interval of the relative gravity variation is half a year, while the absolute gravity are observed once a year. Therefore, the calculation of 2018C1 and 2018C2 measurements were based on the absolute gravity observations in the first part of 2018, data from 2019C1, 2019C2 and 2020C1 are based on the absolute gravity in the first part of 2019, and the 2020C2 measurements is computed from the gravity data of the second part in 2020.

Table 1 shows the optimized SF estimated by means of Bayesian adjustment method and the original SF. In the table, the original SF of 2018C1 is from the calibrated in the long baseline (with the large gravity interval over 1000mGal), original SF of 2018C2, 2019C1, and 2020C1 are calculated from the actual measured data from the classical adjustment method, but the SF of 2019C2 and 2020C2 are calibrated in the short baseline in Yunnan area (with the gravity range of about 340mGal, which is almost covering the maximum GD of the network in Yunnan). Those data in Table 1 indicate that the scale factor of the two gravimeters have changed, and the average changes of the scale factor from original SF to optimized SF are more than 100ppm, and the maximum reached to 230ppm in the three years. However, the optimized SF of the two gravimeters changes synchronously in each period of the campaign, which obviously shows in Table 1 that the difference of the original and optimized SF of two gravimeters are small (differences of SF between two gravimeters is less than 30ppm). That means the correlation between the two gravimeters of the original SF is almost the same to the optimized SF, in each campaign. So we take the observation data of 2020C1 and 2020C2 into detail analysis.

Generally, more than two absolute gravity station values (mutually independent) are introduced into the adjustment for the calibration of scale factor, and the gravity difference between the two absolute stations should be larger enough to covering the maximum GD of the network. In the next section, the scale factor of the six consecutive periods have been optimized, and we compare the difference of observed GD between the two gravimeters. The accuracy of calibration results of the scale factor can be judged by the correlation of GD between the two gravimeters. And the accuracy of the scale factor can be analyzed from the interval difference between the GD of the two instruments. In general, with the accurate scale factor, the interval difference of the GD between the two meters will not increase with the gravity difference between the adjacent stations, and it should has no correlation.

![Fig.4](image_url)

**Fig. 4** The gravity difference of the observed GD between CG5 #1169 and #1170 gravimeter from 2020C1 (a) and 2020C2 (b)

Fig. 4 indicates the gravity difference results of #1169 and #1170 gravimeter in 2020C1 and 2020C2. In which the horizontal axis shows the GD between the adjacent stations, and the vertical axis shows
the gravity differences of GD by two gravimeters. The blue box and purple dot represents the differences from the original SF and the optimized SF respectively. In the similar way, the blue and purple line is the fitted line of the differences from the two gravimeters, and the gravity difference of the gravimeters is less than 30µGal, which is complied with the criterion of gravimetry. The Fig. 4a turns out that slope of the fitted line from the optimized SF is almost horizontal, which means that the optimized SF is accurate, compared with original SF. While, with the original SF, gravity difference by the two gravimeters shows a correlation with the GD, especially in Fig. 4a. Therefore, the optimized SF is better than the original, and the optimized results is more effective for the GD which is more than 100mGal. But for the comparison in the 2020C2 (Fig. 4d), the difference between the two method is gentle. So the cross-verify by absolute gravity values are needed.

4.3. The cross-test of the absolute gravity (AG)

Furthermore, in order to verify the accuracy of optimized SF estimated by the Bayesian method, the survey data of 2020C2 are analyzed, which has enough quasi-synchronous AG values in this period.

Table 2 shows the cross-validation results of different absolute gravity values. In this case, the experiments are designed as follows: One or more absolute gravity values were taken into the adjustment, and the absolute gravity values at other stations were compared with their corresponding values obtained from the original and optimized SF. The results of Table2 show that the scale factor estimated by Bayesian adjustment method is better than those from the classical method. In the case of Kunming station is participated in the adjustment, the other AGs (Funing, Panzhihua, Ruili, Simao, Gengma, Kunming, Xiangcheng and Lijiang) are tested by it. The deviation of the AG values calculated by the optimized SF is smaller than the differences from the original SF. On account of the incorrect of original SF, the gravity difference of tested AG stations (Xiangcheng, Fuinng and Panzhihua), whose gravity values with the large gravity difference from Kunming, is much more bigger. When AG stations (Kunming, Dali, and Funing) are taken into the calculation, the tested differences of the rest AG stations decreased as the increasing number of AG stations taken into the calculation.

Table 2  Cross-validation by using different AG stations (Name of the AG stations are abbreviated; and unit is µGal).

| AG stations used in calculation | AG stations and error | Original SF Difference and error | Optimized SF Difference and error |
|-------------------------------|-----------------------|---------------------------------|---------------------------------|
| KM                           | XC  4.02              | 37.4 8.80                       | 16.7  8.41                     |
|                              | LJ  2.25              | 24.7 3.72                       | 14.4  3.58                     |
|                              | SM  6.93              | 8.7 6.79                        | 7.3   6.50                     |
|                              | DL  1.67              | 4.2 6.55                        | 2.3   6.27                     |
|                              | MZ  7.55              | 8.4 5.33                        | 4.6   5.11                     |
|                              | GM  4.35              | 9.6 8.28                        | 6.2   7.91                     |
|                              | RX  7.03              | 30.9 9.99                       | 10.9  9.24                     |
|                              | FN  3.29              | 35.6 3.79                       | 7.3   3.63                     |
|                              | PZH 4.27             | 48.6 3.70                       | 8.7   3.48                     |

LJ                            | XC  4.02              | 32.4 8.22                       | 11.1  7.92                     |
|                              | LJ  2.25              | 21.4 3.65                       | 10.2  3.54                     |
|                              | SM  6.93              | 7.9 6.33                        | 4.8   6.1                      |
|                              | DL  1.67              | 4.0 5.5                         | 1.2   5.4                      |
|                              | MZ  7.55              | 3.3 4.89                        | 4.5   4.73                     |
|                              | GM  4.35              | 8.9 7.80                        | 2.3   7.52                     |
|                              | RL  7.03              | 26.4 9.48                       | 3.3   9.16                     |
|                              | PZH 4.27             | 37.6 3.14                       | 6.2   3.06                     |

Retracted
Differences of estimated gravity values by using of different AG observations in the network, and the differences are shown in Fig. 5. Associated with Figure 2, it shows that the gravity results calculated by classical and Bayesian adjustment differs greatly in those segments GD values between the two adjacent stations is larger, such as the Xiangcheng area, Panzihua area, and the Mengzi area. The differences of the adjustment results from the two approach decreased with the number of AG stations increasing. And when Kunming is used in the adjustment (Fig. 5a), the gravity differences differs from -60µGal to +40µGal, as using Kunming, Dali, and Funing into the calculation, the range of deceased to -50µGal to +35µGal, even all of the 10 AG values are participated in the adjustment, the differences of gravity results between this two method is about ±30µGal. And the improvement by using optimized SF exhibits obvious differences at the edge of the network.

5. Conclusions and Discussion

Recently, CG-5 relative gravimeters have been widely used in terrestrial gravity measurement. In Yunnan region, the geological background of the survey area is complex, with survey period more than 90 days. Therefore, we adopted the Bayesian adjustment method in this paper, and quantified the influence of the instrument drift and scale factor of the adjustment. Meanwhile, the relative gravity difference (GD) between adjacent station pairs is used instead of the actual gravity measurements obtained at each station as the main object to be analyzed. The n the high quality of adjustment results can be obtained by using this new approach. Through the processing of the gravity observation data in Yunnan network during 2018-2020, and it can be concluded that:

1. Drift characteristics of the two gravimeters in Yunnan area are obviously different, the drift rate of CG5 #1169 gravimeter is nonlinear, while the drift rate of CG5 #1170 shows linear approximately.

2. The correlation of mutual gravity difference between the two adjacent stations of the two gravimeters is analyzed in this study to improve that the optimized scale factor from the Bayesian method is effective to reduce the system errors caused by the inaccurate original scale factor. And the actual calculation results indicate that the difference between the optimized SF and original SF is less than 320ppm.

3. The cross-validation of the absolute gravity results from the quasi-synchronous observation in the network is used in the paper. It is indicated that as the number of absolute gravity (AG) stations increasing, the differences between Bayesian adjustment method and classical adjustment are gradually reduced. And the minimum differences is about ±30µGal.

In conclusion, the Bayesian adjustment method is effective to obtain the accurate scale factor of CG-5 relative gravimeter then to obtain the high precision microgravity in the terrestrial. This method is also suitable for a large range of gravity adjustment of the joint gravity network. And it can also reduce the cost of scale factor calibration effectively.
Acknowledgments
Supported by China Earthquake Administration (grant No: 2020010204 and 2021010207) and Institute of Earthquake Forecasting, China Earthquake Administration (grant No: 2019CSES0105).

References
[1] Van Camp M, de Viron O, Avouac JP (2016) Separating climate-induced mass transfers and instrumental effects from tectonic signal in repeated absolute gravity measurements. Geophys Res Lett 43(9):4313–4320.
[2] Van Camp, M., Vanclooster, M., Crommen, O., Petermans, T., Verbeeck, K., Meurers, B., van Dam, T., and Dassargues, A. Hydrogeological investigations at the Membach station, Belgium, and application to correct long periodic gravity variations, J. Geophys. Res., 2006, 111: B10403.
[3] Ophaug, V., Breili, K., Gerlach, C., Omholt Gjevestad, J. G., Lysaker, D. I., Dahl Omang, O. C., & Pettersen, B. R. Absolute gravity observations in Norway (1993–2014) for glacial isostatic adjustment studies: The influence of gravitational loading effects on secular gravity trends. Journal of Geodynamics, 2016, 102: 83–94.
[4] Hare J L, Ferguson J F and Brady J L. The 4D microgravity method for waterflood surveillance: IV. Modeling and interpretation of early epoch 4D gravity surveys at Prudhoe Bay, Alaska Geophysics 2008, 73-6: WA173–80.
[5] Williams-Jones G, Rymer H, Mauri G, Gottsmann J, Poland N, Carbone D. Toward continuous 4D microgravity monitoring of volcanoes. Geophysics 2008, 73: WA19–WA28.
[6] Chen Y T, Gu H D, Lu Z X. Variations of gravity before and after the Haicheng earthquake, 1975, and the Tangshan earthquake, 1976. Phys. Earth Planet Inter, 1979, 18: 330–338.
[7] Kuo J T, Yue-Feng S. Modeling gravity variations caused by dilatancies[J]. Tectonophysics, 1993, 227(1): 127-143.
[8] Imanishi Y, Sato T, Higashi T, Sun W and Okubo S. A network of superconducting gravimeters detects submicron coseismic gravity changes Science 2003, 306: 476–8.
[9] Zhu, Y. Q., F. B. Zhan, and J. C. Zhou (2010), Gravity measurements and their variations before the 2008 Wenchuan earthquake. Bull. Seismol. Soc. Am., 10(5B), 2815–2824.
[10] Zhu, Y. Q., W. F. Liang, F. B. Zhan, F. Liu, Y. M. Xu, S. S. Gou, and L. Liu (2012), Study on dynamic change of gravity field in China continent [in Chinese], Chin. J. Geophys., 55(3), 804–813.
[11] Chen S, Liu M, Xing L, Xu W, Wang W, Zhu Y, Li H. Gravity increase before the 2015 Mw7.8 Nepal earthquake. Geophys Res Lett, 2016.
[12] Chen, S., C. S. Jiang, and J. C. Zhuang (2015), Statistical evaluation of efficiency and possibility of earthquake predictions with gravity field variations and its analytic signal in Western China, Pure Appl. Geophys., 1–15.
[13] Lederer M. Accuracy of the relative gravity measurement [J]. Acta Geodinamica et Geomatetalia, 2009, 6 (3) : 383-390.
[14] SCINTREX LCG-5 Scintrex autograv system operation manual, part #867700 Revision7. Scintrex Limited, Concord[M]. 2012.
[15] CROSSLEY. D., H. JACQUES, and R. UMBERTO. The measurement of surface gravity [J]. Reports on Progress in Physics, 2013, 76(4): 046-101
[16] Akaike H. Likelihood and the Bayes procedure. In: Bernardo JM, DeGroot MH, Lindley DV, Smith AFM (eds) Bayesian statistics. University Press, Valencia, 1980, pp 143–166.
[17] CHEN S, ZHUANG J iangcang, LI Xiaoyi, et al. Bayesian approach for network adjustment for gravity survey campaign: methodology and model test [J]. Journal of Geodesy, 2019, 93(5): 681-700.
[18] Onizawa, S. Apparent calibration shift of the Scintrex CG-5 gravimeter caused by reading-dependent scale factor and instrumental drift. J Geod 2019, 93: 1335–1345.
[19] WANG Linhai, CHEN Shi, ZHUANG Jiancang, et al. Bayesian estimation of the scale factor of relative gravimeter in precise gravity survey. Acta Geodaetica et Cartographica Sinica, 2020, 49(12): 1543-1553 (in Chinese).