ISSN 2616-5872 Vol.7, Issue 4: 41-48, DOI: 10.25236/AJEE.2025.070405

Study on Observation Results and Interference Characteristics of Huaibei Station Gphone Gravimeter 2010-2015

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Abstract: *This study analyzes continuous gravity observations from the Huaibei GPhone gravimeter (2010-2015) through systematic data processing and quality assessment. The raw data were preprocessed using TSoft software to eliminate tidal components (solid earth tide, ocean tide loading, polar motion correction) with local atmospheric pressure compensation and segmented drift fitting, yielding refined non-tidal signals. A tripartite evaluation framework incorporating conventional assessment, Nakai statistical testing, and harmonic analysis was implemented to examine data quality and anomalous deformation patterns. Key findings reveal: (1) Distinct seasonal variations in tidal gravity signals, particularly in the M2 wave component showing amplitude stability within 0.001; (2) Primary interference factors including power outages (causing 12-72 hour data gaps), pendulum adhesion events (inducing 0.5-1.2 μGal offsets), anthropogenic disturbances (generating 0.3-5.0 μGal noise), and typhoon impacts (correlating with 0.8-1.5 μGal deviations). Comparative analysis with superconducting gravimeter data confirms the GPhone's reliability under normal conditions (DRMS <0.2 μGal), though extreme weather resilience requires improvement. This work establishes a reference protocol for environmental noise identification in spring gravimeter observations.*

Keywords: *Continuous Gravity Mass Assessment, Interference Characteristics, High-Frequency Information*

1. Introduction

Huaibei Earthquake Station (hereinafter referred to as Huaibei Station) continuous gravity reference station is a Chinese mainland structural environmental monitoring network project during the 11th Five-Year Plan period. The instrument is installed in October 2009, and the observation instrument is the GPhone type spring gravimeter produced by Gray Company of the United States. The instrument has been transformed and improved by Wuhan Earthquake Research Institute, and integrates an integrated system of observation, data collection, data storage, data transmission and data real-time monitoring. The sampling interval is 1 / S, and it outputs 12 auxiliary measurement items. Huaibei Taiwan gravity observation system has been in operation for many years, with stable output data, rich data amount, and clear gravity solid tide form. After several years of operation, gravity observation has accumulated rich and continuous data in Huaibei station. Huaibei platform is complete, and the data observation quality has been among the best in the previous national evaluation. Therefore, through the evaluation of the data, the overall operation condition of the gravity observation instrument can be fully reflected. Based on this consideration, this paper using the Huaibei Gphone gravimeter 2010-2015 observation results, the Huaibei Gphone gravimeter observation internal accuracy indicators such as comprehensive quality assessment, analyze the data interference, extract the interference abnormal features, so as to have a more thorough understanding of the digital gravity data observation quality, change characteristics, accurate identification of anomaly, better realize the effective use of digital gravity observation in earthquake prediction.

2. Gravity observation environment of Huaibei Platform

Huaibei platform is located at the junction of Jiangsu, Shandong, Henan and Anhui provinces, about 120 Km away from the west side of tan-Lu fault zone. The station is built on the anticline south wing of Xiangshan, with the east and the plain on the west. The outlet of the mountain around the Cambrian and Ordovician limestone; the quaternary is covered by alluvial and alluvial gravel and red clay. The

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gravity observation instrument is installed in the station deformation observation cave, the cave belongs to the local civil air defense cave, the cave is ordovician limestone, the rock formation is nearly upright, the fissure development, the cave is 160m deep, covering more than 50m, the vegetation is crown, arbor forest and weeds. The gravity observation room is 60m away from the hole, with four sets of sealed cabin doors. The temperature in the hole is 15.8℃, and the annual and daily temperature changes meet the requirements of the observation "code".

3. Procedures and results of non-tidal signal processing for gravity data of Huaibei seismic platform

The observation data of Huaibei gravity station from January 2012 to June 2016 in the terrestrial network were selected. In order to obtain the non-tidal signal of Gphone observation data, the data processing is mainly divided into the following steps: data pretreatment, correction of solid tide effect, correction of tidal load effect, correction of polar shift gravity effect, correction of atmospheric load effect and correction of instrument drift effect. Using the Huaibei Gravity Station as a case study, this section details the procedures and outcomes of gravity data processing.

3.1 Data preprocessing

The original observation of the gravimeter is the second sampling data. Firstly, the low-pass filter with a cut-off frequency of 720 cpd (cycleper day) is used to reduce the original sampling data; then, the low-pass filter with 12 cpd is used to resample the minute sampling data to the hourly data; finally, the gravity data processing software is used to correct the jump, step, earthquake and intermittent data by Tsoft. Figure 1 (a) shows the results of observation data from Huaibei Station.

3.2 The solid tide

The main signal source of the observation of the gravity station is the periodic change of gravity on the earth surface caused by the gravity of the earth, namely the gravity solid tide [1]. In this paper, the DDW model [2] is used to correct the solid tide signal in DW data. The wave groups considered are mainly half-daily to long-periodic tides. Figure 1 (b) is the theoretical solid tidal gravity signal of the Huaibei Earthquake platform, with its amplitude exceeding 100μGal.

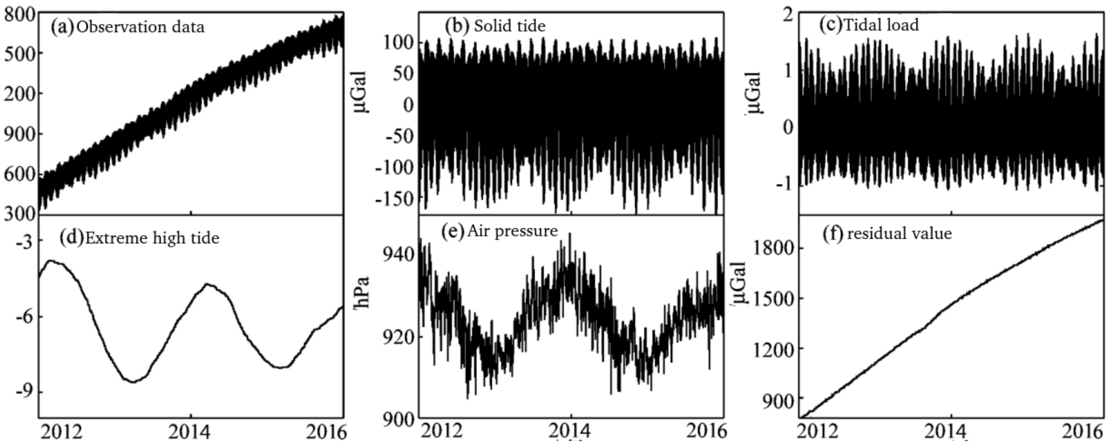

Figure 1 Data processing results of Huaibei Earthquake Station

(a) Gravity observation data; (b) Solid tide gravity change; (c) Sea tide load gravity change; (d) Polar shift gravity effect; (e) Pressure observation value; (f) Gravity residual value

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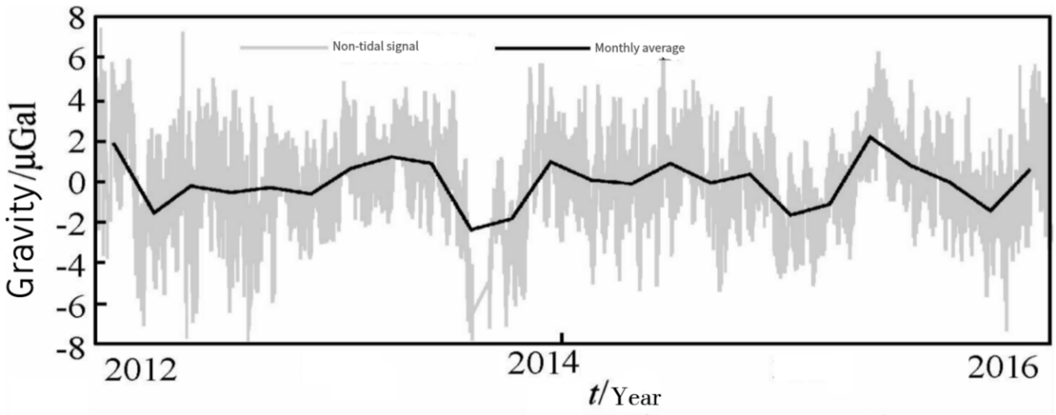

Figure 2 Non-tidal signal and monthly mean value of the gravity observation data of Huaibei Station

3.3 Sea tide load

NA099 tidal model is used to calculate the gravity effect of the main 8 tidal components (K1, O1, P1, Q1, Q 1, K2, K 2, M2, N2, S2). See Figure 1 (c) Huaibei platform is far from the coastline, and the signal amplitude of tidal load is small, about 1.5μGal.

3.4 Polar shift gravity effect

The polar shift causes the change of centrifugal acceleration and daily length (LOD) of the earth, which then causes the change of the earth's gravity field. The change of gravity at any point of the earth surface caused by polar shift can be calculated according to the change of the geographical and polar coordinates of the point. The change of polar coordinates can be obtained from the earth rotation parameters provided by IERS (International Earth Rotation Service). According to the relevant theoretical formula [3], the effect of polar shift gravity at a point on the ground can be calculated. According to Figure 1 (d), the amplitude of the polar shift gravity effect in Huaibei station is about 6μGal.

3.5 Atmospheric load effect [3]

The influence of atmospheric load on gravity tidal observation consists of three parts: the direct effect caused by the change of atmospheric mass; the deformation effect of the elastic earth under the action of atmospheric mass load; the change of the earth tide level caused by the redistribution of the internal mass [4]. The pressure of the station is the main contributor to the residual of gravity tidal observation data, and the influence of the atmospheric load in the near area of 0.5° from the station can account for more than 90% of the gravity signal change caused by the global pressure change. If there is station pressure data [5], only using the pressure observation data to correct can meet the calculation requirements [3]. The continuous gravity station in the land network simultaneously records the environmental elements of atmospheric pressure, such as temperature change. Figure 1 (e) shows the atmospheric pressure change of Huaibei station, which shows that the atmospheric pressure change is obviously seasonal. In this study, the gravity effect of atmospheric load is-0.3 μ Gal / hPa at 1 hPa (1 hPa = 100 Pa).

3.6 Drift correction

Because the gravity tidal observation is affected by the instrument drift, pendulum adjustment and other factors, the data still has drift after the above tidal signal correction. Due to the diversity of instrument drift, the segmented curve fitting [6]. Figure 1 (f) is the residual amount of gravity tidal observation data [Figure 1 (a)] after deducting the effect of tidal [Figure 1 (a), Figure 1 (c), Figure 1 (d)]and atmospheric pressure [Figure 1 (e)]. It can be seen that this residual amount has a significant drift upward trend. After data processing in the above several steps, Figure 2 presents the final result of the non-tidal gravity signal (gray line in the figure) extracted in Huaibei Station. After the drift correction, the instrument drift effect present in Figure 1 (f) has been effectively removed, and the residual gravity shows a significant seasonal variation.

4. Quality Assessment results of the tidal signal observation of the gravimeter

First, the general assessment of data quality in terms of continuous rate, annual variation and annual zero drift is shown in Table 1. The continuous rate of gravimeter observations is 98.89%. As can be seen from Table 1, 2010 and 2011 are the initial stage of instrument installation and operation, with more invalid data due to debugging instruments and other reasons, and the continuous rate is relatively low. Figure 3 illustrates the gravimeter's digital observation record at Huaibei Station. The general trend is positive zero drift. The annual variation and annual zero drift value of the instrument in 2011-2013 were relatively stable, and the annual variation and annual zero drift value in 2014, indicating that the instrument base block and working state of the observation system gradually stabilized.

Table 1 General assessment of observation data quality of gPhone Gravitimeter

General evaluation index	a particular year						mean
	2010	2011	2012	2013	2014	2015	
Continuous rate (%)	96.04	97.65	99.99	99.88	99.80	100.00	98.89
Annual variation (ug)	4692.52	3340.28	2900.35	3052.69	2075.33	1995.91	3009.51
Annual zero drift (ug)	4410.59	2920.69	2735.59	2663.24	1655.98	1806.00	2698.68

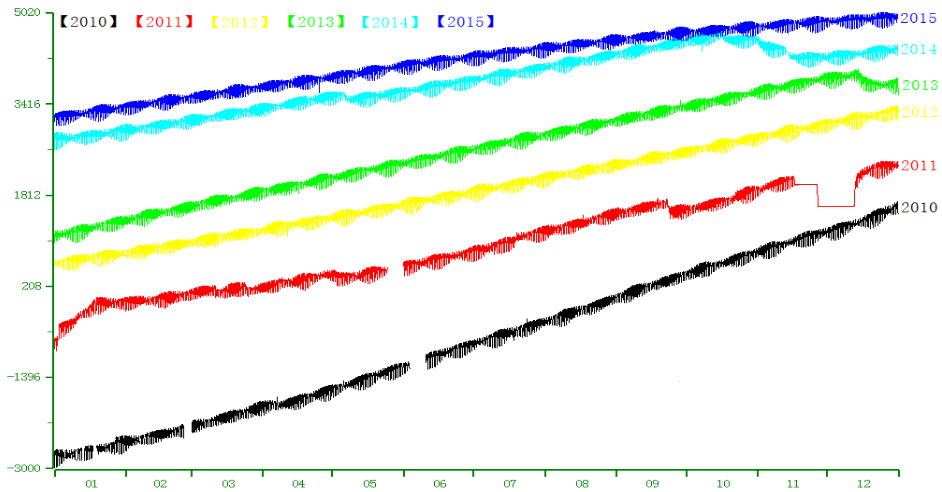

Figure 3 Time series of continuous gravity annual change in Huaibei Station

4.1 Nakai fitting test

The intrinsic mass of the continuous gravity data was examined overall, with least-squares fitting using Nakai proposed method relative to each independent 48 h array separated by the Venydikov digital filter, with data quality judged by the fitting results shown in Table 2. In 2010 and 2011, the tidal lag factor was greater than 1.5, and the tidal factor from 2012 to 2015 was 1.150-1.157, within the theoretical average of 1.16; in 2013,0.1108°; the overall drift coefficient and mean variance of the observed data from 2010-2015 became more and more stable.

4.2 Venidekov harmonic analysis

Through vnidikov digital filtering harmonic analysis method of gravity data files according to the annual solution tide parameters, with reference to the tidal wave tidal amplitude screening six main wave group, respectively is Sunday wave O1 (the main daily wave), P1 (sun main wave), K1 (the sun of the main red tail wave) and diurnal wave 2N2 (the main elliptical diurnal wave of the moon), M2 (the main half durnal wave of the moon), S2 (the main half diurnal wave of the sun), see table 2.

In the annual harmonic analysis of gravity tidal parameters of Huaibei Platform, the tidal factors of P1, K1 and 2N2 waves exceed 0.01, the O1, M2 and S2 waves are relatively stable, and the tidal factors of O1 and M2 waves are around 1.16. In the harmonic analysis of 2010-2015, the error of each

ISSN 2616-5872 Vol.7, Issue 4: 41-48, DOI: 10.25236/AJEE.2025.070405

harmonic tidal factor in 2015 was the smallest, among which the error of M2 wave tidal factor was 0.00036 less than 0.0005. The error in the multiple tidal factor in 2013 was the highest value, which can be considered that the tidal factor in 2015 is very stable and relatively unstable in 2013.

Table 2 Nakai test results of gravity data of Huaibei Station

time	The tidal amplitude ratio	Tidal lag factor	A drift	mean square deviation
2010	1.614	0.0156	0.5711	0.963
2011	1.577	0.0306	0.4991	1.160
2012	1.160	0.0345	0.3780	0.954
2013	1.157	0.1108	0.4003	0.768
2014	1.157	0.0223	0.3167	0.778
2015	1.158	0.0160	0.2143	0.594
MEAN	1.304	0.0383	0.3966	0.870

5. Data analysis with morphological characteristics

Continuous gravity observation interference can be divided into long-term interference and short-term interference[7], Huaibei continuous gravity since October 2009, stable operation, can clearly record the solid tide change and seismic wave, data second sampling, high frequency information rich, observation data interference by various factors, human factors, environmental factors, the affected curve also has different performance.

5.1 Failure of the power supply system

The failure of power supply system mainly refers to the power failure due to thunderstorm weather, mains maintenance, poor contact with power supply lines, etc. If the power failure is long, the USP power is exhausted and the instrument stops working. gPhone Continuous gravimeter adopts fully closed structure, working under the state of constant temperature, constant pressure, observation instrument demanding power supply system, power outage may lead to the instrument observation environment of constant temperature system damage, the stability of observation data for a long time, from the operation of more than six years, power supply system failure is the primary factor affecting the instrument observation.

On September 23, 2011, mains was cut off at 06:00 due to line maintenance, cave UPS was exhausted at 8:00, power supply was restored at 12:00, and power was off for 4 hours. Due to the power failure of the gravimeter, after the power supply was restored, the curve produced peak interference, and the value began to fall from a large jump. Due to the short downtime, with little impact on the observation system, the value was basically restored to the normal change level after 150 minutes as shown in Figure 4.

5.2 Instrument failure

Analysing the observed data since operation, it is found that the abnormal data caused by the failure of the instrument itself is mainly the instrument adhesion. On November 17, 2011, the observation system appeared in Figure 5, the observation data rose to 288710-8 m·s-2610-8 m·s-2. The data curve had no solid tide pattern, the high frequency disturbance near 14200010-8 m·s-2, and the shutdown and remote control of the instrument parameters, the instrument returned to normal.

5.3 Human interference

The mobile gravity observation point of Huaibei Station is located in the same observation room as the continuous gravity observation. Every year, different units such as Earth Institute, Wuhan Institute and Provincial Engineering Institute come to Huaibei to conduct the mobile gravity measurement, which will cause certain interference to the continuous gravity observation curve. In addition, in the daily maintenance of the gravity meter, it needs to enter the hole for the instrument maintenance and debugging, which will also produce inevitable interference to the data. According to the variation of data, there is no fixed disturbance feature, most of which are short-time jump, large steps or continuous curve distortion and the number of broken pieces. Figure 6 shows the sudden interference caused by the

ISSN 2616-5872 Vol.7, Issue 4: 41-48, DOI: 10.25236/AJEE.2025.070405

geophysical hole measurement at 20:00 on May 8, 2014.

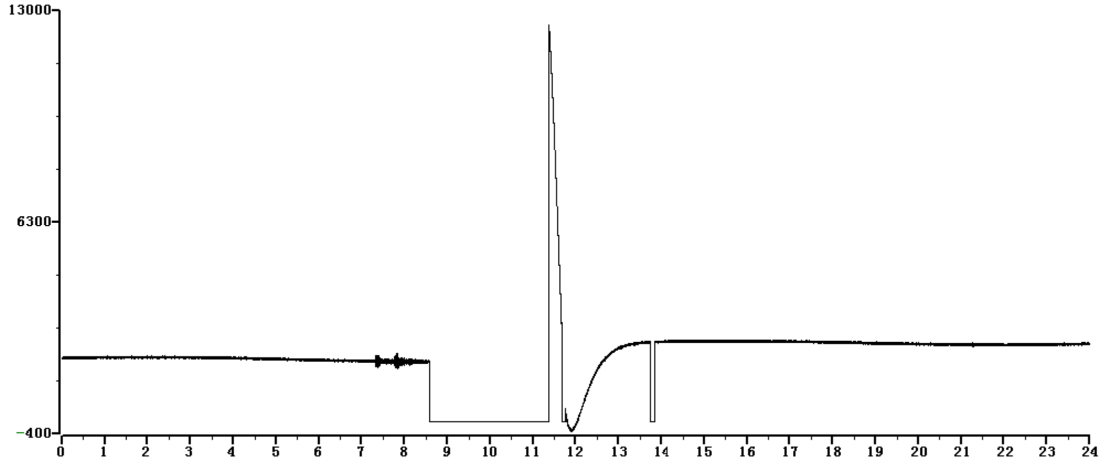

Figure 4 Impact of power failure

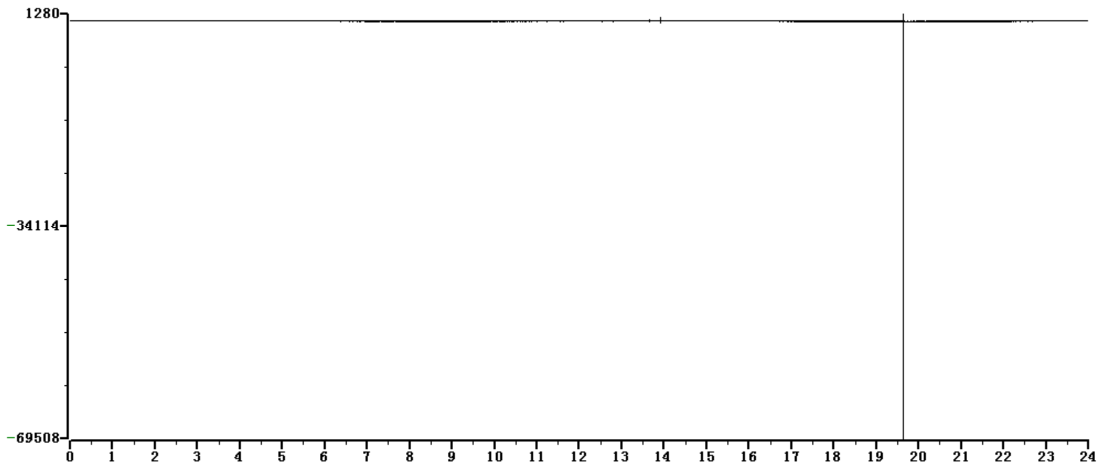

Figure 5 Human hole interference

5.4 Interference of meteorological factors

The main meteorological factors include temperature, pressure, precipitation, strong wind, etc. According to the observation of the three meteorological elements of Huaibei Taiwan, it is found that gravity observation is not obviously affected by the three elements of meteorology. Does windy weather have an impact on gravity observation? Many scholars have found that the disturbance of gravity high frequency signal is related to typhoon weather [8] . The author found the observational data of typhoon in 2015. Among them, the 13th typhoon "Sudiruo" landed in Putian, Fujian province on August 8, and had an impact on the city on August 10. The observation data showed that the curve high frequency signal enhancement on August 8 and 9 see Figure 6.

5.5 Gravity change before magnitude 4.7 and magnitude 7.2 in the East China Sea

On October 24, 2010, Ms4.7 earthquake occurred in Zhoukou, Henan province. The epicenter was 197.5 kilometers away from the station. The seismic wave was clearly recorded by the continuous gravimeter, the maximum amplitude was 19174 μg, the duration was 6min, and the response form was pulse. The discrete orthogonal wavelet transformation of the original gravity data shows that there was a "gravity disturbance" before the earthquake (see Figure 6). The disturbance lasted for 5 days from October 20 to October 24, and the morphological characteristics were spindle-shaped. Figure 6 shows the MS 4.7 earthquake in the East China Sea on October 24, 2010, with the epicenter distance of 11 03 Km. It can be seen that there was also a spindle-like "gravity disturbance" before the high-frequency data curve, which began to appear 7 days before the earthquake and lasted for 3 days.

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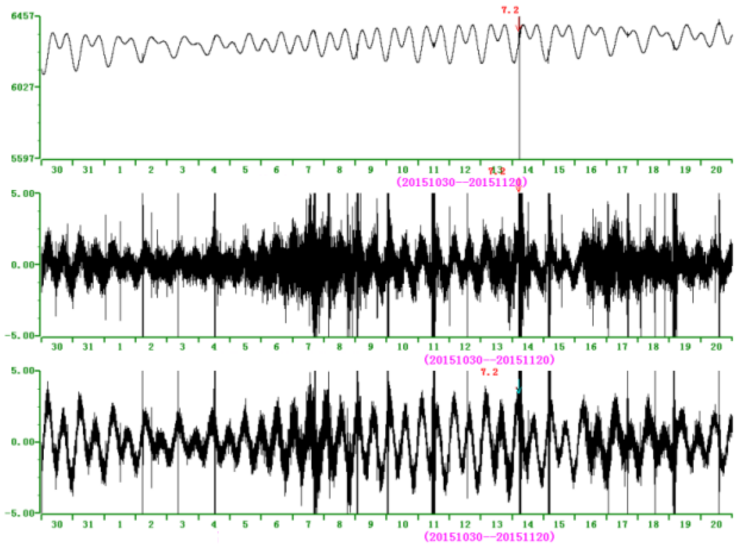

Figure 6 Huaibei gPhone gravity meter in Zhoukou 4.7 earthquake

6. Results and discussion

Through the analysis of Huaibei ghone continuous gravimeter:

(1) The Tsoft software was used to preprocess the observation data of the gravimeter, deducting the effects of solid tide, tidal load, polar shift, atmospheric pressure and instrument drift in the observed signal, and the non-tidal gravity signal of Huaibei station was obtained, which showed obvious seasonal changes.

(2) The technical indicators of the annual evaluation and scoring of national continuous gravity observation data mainly assess three contents, including observation accuracy, data integrity rate and data continuous rate. The observation accuracy evaluation content is that the relative error of M2 wave tidal factor is higher than 0.001, and the data integrity rate and operation continuous rate are higher than 99.5%. In 2014 and 2015, the relative error of M2 wave tidal factor reached within 0.00073. The data of various indicators show that the Huaibei continuous gravity meter observation system has entered or approached the operation stability period, and the system operation management and data observation quality have reached the excellent level of national continuous gravity observation.

(3) The gravity meter is mainly affected by various disturbance factors in the operation process. The power failure, adhesion, human disturbance, strong typhoon and so on are the main reasons that affect the continuous rate and observation quality of the instrument.

(4) The application of digital second sampling technology of continuous gravimeter can not only record long periodic variable waves, but also record high frequency information such as medium-strong seismic waves and ground pulsation in the region.

Acknowledgements

2022 Monitoring, Forecasting and Scientific Research Projects (3 JH-202201042), China Earthquake Administration 2019 Earthquake Science and Technology Spark Program (XH19018YSX), and the Open Fund of Wuhan Gravity and Solid Tide National Field Scientific Observation and Research Station (WHYWZ202110).

References

[1] Sun Heping, Xu Houze, Xu Jianqiao, et al. Observation of the tidal changes of the gravitational field and its study [J]. Progress in Earth science, 2000, 15 (1): 53-57.
[2] Dehant V, Defraigne P, Wahr J. Tides for a convective Eatrth[J]. Journal of Geophysical Research,

ISSN 2616-5872 Vol.7, Issue 4: 41-48, DOI: 10.25236/AJEE.2025.070405

1999, 104(B1): 1035-1058.
[3] Daniel Chan. Preprocessing and analysis of solid tide observation data of Wuhan Jiufeng tai superconducting gravimeter [D]. The Graduate School of the Chinese Academy of Sciences, 2003.
[4] Sun Heping, Xu Houze, Tao Guoxiang, et al. Earth tidal constants with superconducting gravitometers [J]. Crustal deformation and earthquake, 1997, 17 (4): 17-25.
[5] Sun Heping. The Atmospheric gravity Grynynn's function [J]. Scientific Bulletin, 1997, 42 (15): 1640-1646.
[6] VXu Weimin, Chen Shi, Gao Mengtan, et al. A preliminary analysis of the non-tidal characteristics of Chinese mainland gravitational field [J]. Progress in Geophysics, 2012, 27 (3): 861-871.
[7] Zhong Jimao, Guan Yumei, Yang Jinling. The activity characteristics of Typhoon Madm were studied with the continuous gravity data of Fujian province [J]. Journal of Earthquake Engineering, 2015, 37 (12): 1092-1094.
[8] Tao Fangyu, Lu Dongliang, Wang Fei, et al. Analysis and judgment of data characteristics of Huaibei Taiwan gPhone gravimeter [J]. Geodey and geodynamics, 2017, 37 (added 1): 62-65.