



Data Article

Dataset from Scintrex CG-5 gravity meters acquired at the Zhetygen calibration line in Kazakhstan



Roman Sermiagin^{a,*}, Yeraly Kalen^b, Nurgan Kemerbayev^c,
Khaini-Kamal Kassymkanova^d, Nikolay Kosarev^e,
Guzyaliya Mussina^c, Assel Batalova^c

^a RSE National Centre of Geodesy and Spatial Information, 20 Mangilik El Ave Astana, 010000, Kazakhstan

^b SPC Geoken LLP, Almaty, Kazakhstan

^c GEOID LLP, Astana, Kazakhstan

^d Satbayev University, Almaty, Kazakhstan

^e Siberian State University of Geosystems and Technologies, Novosibirsk, Russia

ARTICLE INFO

Article history:

Received 25 September 2024

Revised 3 November 2024

Accepted 12 November 2024

Available online 23 November 2024

Dataset link: [Observation files of CG-5 gravity meters for the Zhetygen calibration line for five years \(Original data\)](#)

Keywords:

Relative gravity meter

Gravimeter

Gravity meter calibration

Gravity meter measurements

Free fall acceleration

CG-5 gravity meter

ABSTRACT

The article provides a dataset derived from Scintrex CG-5 gravity meter observation files collected during five years of annual measurements along the Zhetygen calibration line utilizing three meters. Geoken, a Kazakhstani enterprise, routinely conducts these measurements to calibrate its meters necessary for manufacturing operations.

Researchers can use this constantly updated dataset to study the behavior of the CG-5 gravity meters' calibration function in time and the measurement range. The measurement range is 100,900 μGal .

© 2024 The Author(s). Published by Elsevier Inc.

This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>)

* Corresponding author.

E-mail address: roman.sermiagin@gmail.com (R. Sermiagin).

Social media: [@r_sermiagin](#) (R. Sermiagin)

Specifications Table

Subject	Earth and planetary sciences
Specific subject area	Geophysical and geodesy methods
Type of data	Raw, special data format
Data collection	Long-term annual measurements of gravity at calibration line stations using Scintrex CG-5 gravity meters
Data source location	Almaty in Kazakhstan, Geoken LLP
Data accessibility	Repository name: Zenodo Data identification number: DOI: 10.5281/zenodo.13737696 Direct URL to data: 10.5281/zenodo.13737696
Related research article	R. Sermiagin, N. Kemberbayev, K.-K. Kassymkanova, G. Mussina, M. Shkiyeva, N. Kosarev, K. Samarkhanov, A. Batalova, A. Rakhimzhanov, Y. Kalen, Selection of a calibration system for relative gravimeters and testing of the processing using the example of the Zhetygen calibration baseline in Kazakhstan, Acta Geodaetica et Geophysica (Sep. 2024), doi: 10.1007/s40328-024-00454-x .

1. Value of the Data

- These data comprise systematically gathered annual observations utilizing identical gravity meters at fixed points over five years.
- Researchers in gravimetry and geophysics may utilize this dataset for metrological investigations of spring gravimeters across various observations, particularly over time.
- Researchers and developers may utilize this dataset to evaluate the methodologies and algorithms for processing the measurement outputs of the Scintrex CG-5 and CG-6 spring gravimeters.
- The dataset has a substantial number of observations that researchers can utilize to examine the implementation of diverse statistical processing algorithms and least squares techniques, including outlier rejection and various least squares models.

2. Background

For several years, Geoken, a geophysics firm based in Kazakhstan, has conducted annual calibrations of its gravity meters, assessing the parameters of its calibration function at the Zhetygen calibration line, about 20 km south of Almaty, Kazakhstan. All measurement data from the gravimeters is meticulously organized and compiled. This study presents findings from three Scintrex CG-5 gravity meters conducted between 2019 and 2023. Researchers investigating spring gravity meters, namely the Scintex CG-5 and CG-6 models, may consider this dataset useful.

The fundamental value of this data lies in the repeated annual measurements at the same stations, utilizing same meters and measurement techniques. This dataset offers a significant chance to examine the temporal fluctuations in the calibration function of the Scintrex CG-5 gravity meters.

3. Data Description

3.1. Calibration line

The Zhetygen calibration line is a set of special stations fixed on the ground, designed to perform measurements with different models of spring gravity meters, such as Scintrex CG-5, CG-6, LaCoste & Romberg, etc. The gravimetric stations are rectangular concrete piers with 1 × 1 m at the top for station № 1 and 2 × 1 m for all the other stations. The pedestals were dug into the ground to a depth of up to 2 m. For ease of work, covers like a bus station are built over the

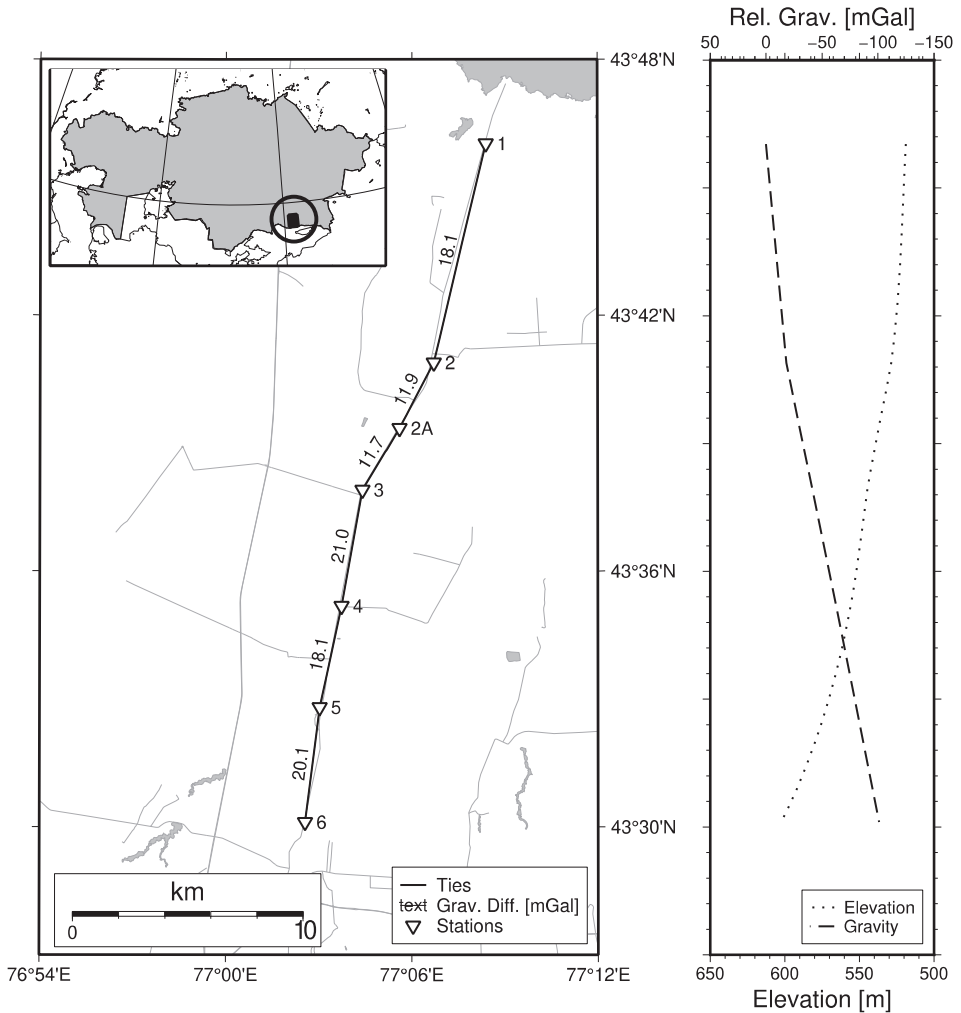


Fig. 1. Location of the Zhetysay calibration line stations and changes in gravity and height along the line.

pedestals to protect the meters and operators from precipitation and wind gusts. Operators can install up to 6 gravity meters simultaneously.

The stations are located from north to south between the Kapchagay reservoir and Almaty. The total length of the line is 30 km, with a height difference of 105 m, corresponding to a change in gravity in this area of approximately 100 mGal. The map of the gravimetric calibration line and the coordinates of the stations are shown in Fig. 1 and Table 1, respectively. The plot on the right shows changes in gravity and height along the calibration line's profile.

3.2. Setup settings of gravimeters and data files

Scintrex CG-5 gravity meters are high-precision instruments for measuring the difference in gravity with an accuracy of 5 μGal ($1 \mu\text{Gal} = 10^{-8} \text{ m/s}^2$). The reading resolution of this instrument is 1 μGal [1].

Table 1
Stations of the Zhetygen calibration line.

St. Name	Latitude [°N]	Longitude [°E]	Elevation [m]	Distance [km]	Rel. Gravity [mGal]
1	43.767118	77.139850	487	0.0	0
2	43.681501	77.111867	515	9.8	−18.1
2A	43.655873	77.093458	530	13.0	−30.0
3	43.631756	77.073505	547	16.1	−41.7
4	43.586310	77.062245	563	21.3	−62.7
5	43.546706	77.050521	573	25.8	−80.8
6	43.501888	77.042719	592	30.8	−100.9

Table 2
Critical setup setting of CG-5 gravimeters.

Section	Parameter	Value
Grid Reference	Latitude	43.7 N
	Longitude	77.1 E
	UTM Zone	43
	GMT Diff.	−6.0
Station Designation System	System	XYm
Autograv Setup	Tide Correct.	Yes
	Cont. Tilt. Corr.	Yes
	Auto Reject.	Yes
	Terrain Corr.	No
	Seismic Filter	Yes
	Save Raw Data	No
Options	Read Time	40
	#Of Cycles	4–10
	Record Amb. Temp	Yes

Gravity meters with serial numbers 40823, 40824, and 49459, owned by Geoken LLP, performed the measurements. [Table 2](#) below provides the critical settings of the meters used during all surveys.

3.3. File format

Files can be obtained from CG-5 gravity meters in several formats: a binary file in the GeoSoft software format and two versions of a text table – with and without information headers. We present the data in the standard Scintrex CG-5 text format with headers (a file fragment is in [Appendix A](#)).

[Appendix B Table 4](#) describes the file headers and columns. The first two columns depend on the **Station Designation System** → **System** (see [Table 2](#)). They can also display coordinates in the Universal Transverse Mercator projection or latitude and longitude. With the appropriate settings, the column names will change. The third column, **ALT.**, is also customizable and can display **Altitude** or, if the **Options** → **Record Amb. Temp** option is enabled, and the ambient temperature (in this case, the column name does not change).

4. Experimental Design, Materials and Methods

4.1. Measurement technique

We used a step method (double loop) to account for the meter drift, performing measurements at each point at least three times in the sequence a – b – a – b – c – b – c – ... (see

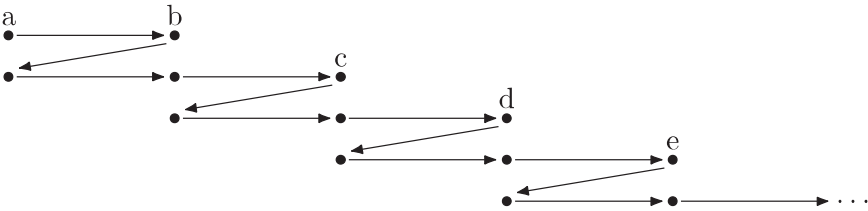


Fig. 2. Stepwise measurement method with a relative gravimeter.

Table 3
Schedule of execution and duration of measurements.

Campaign	Date	Meter	Duration [hour]
May 2019 Feb 2020	2019/05/23–26	49,459, 40,823, 40,824	9.6, 8.7, 8.8, 7.5
	2020/02/12,16–17	49,459	7.0, 8.1, 8.1
	2020/02/12–13,15	40,823, 40,824	7.0, 6.7, 7.1
Sep 2021	2021/09/18–20	49,459, 40,823, 40,824	10.1, 19.1, 10.5
Feb & Mar 2022	2022/02/26–28	49,459	8.5, 8.0, 7.8
	2022/03/29–31	40,823, 40,824	7.9, 7.1, 7.3
	2022/11/18,21,23	49,459, 40,823, 40,824	8.7, 9.6, 9.4
Nov 2022	2022/11/18,21,23	49,459, 40,823, 40,824	8.7, 9.6, 9.4
Dec 2023	2023/12/07–09	49,459	9.6, 7.8, 7.7
	2023/12/11–12,19	40,823, 40,824	8.7, 8.3, 8.2

Fig. 2). This approach allows for the evaluation of short-period drift. In this case, we performed measurements in both the forward and reverse directions, allowing for the review of long-period drift based on repeated observations at the initial (first) station [2].

Operators performed 4 to 10 measurements (readings) at the station each time. Each reading is the mean of a 6 Hz signal over a time corresponding to the **Read Time** setting (see Table 2). The **# Of Cycles** parameter determines the number of mean records.

In addition to the calibration line stations, operators also performed control measurements at station No. 10 in the Geoken LLP laboratory. These measurements were not used to evaluate the calibration function but can also be used to estimate the long-term drift.

4.2. Measurement execution schedule and dataset volume

As already noted, the dataset contains six campaigns over five years. Each campaign included three cycles of daily measurements. Two or three operators transported the meters using light vehicles. Table 3 presents the measurement schedule. The total dataset volume contains 27 days of observations by 3 gravity meters for 7–10 working hours and is stored in 55 files.

4.3. Correcting data files

The original dataset contains numerous errors related to inaccurate station name entries. The operator consistently neglected to alter the name when transitioning to the subsequent station. Manually identifying such problems would require examining all 10,420 records over 55 files. To partially automate this process, similar inaccuracies were detected through residuals in the adjustment procedure [3].

All issues about erroneous station names have been fully resolved. We developed the design matrix using the “get_dummies” function from the Pandas Python module to the column containing station names for each measurement (reading) to achieve this. The system was resolved to utilize the classical least squares method with the “OLS” model from the “statsmodels” package. Consequently, if the station name is erroneous, the residuals associated with the

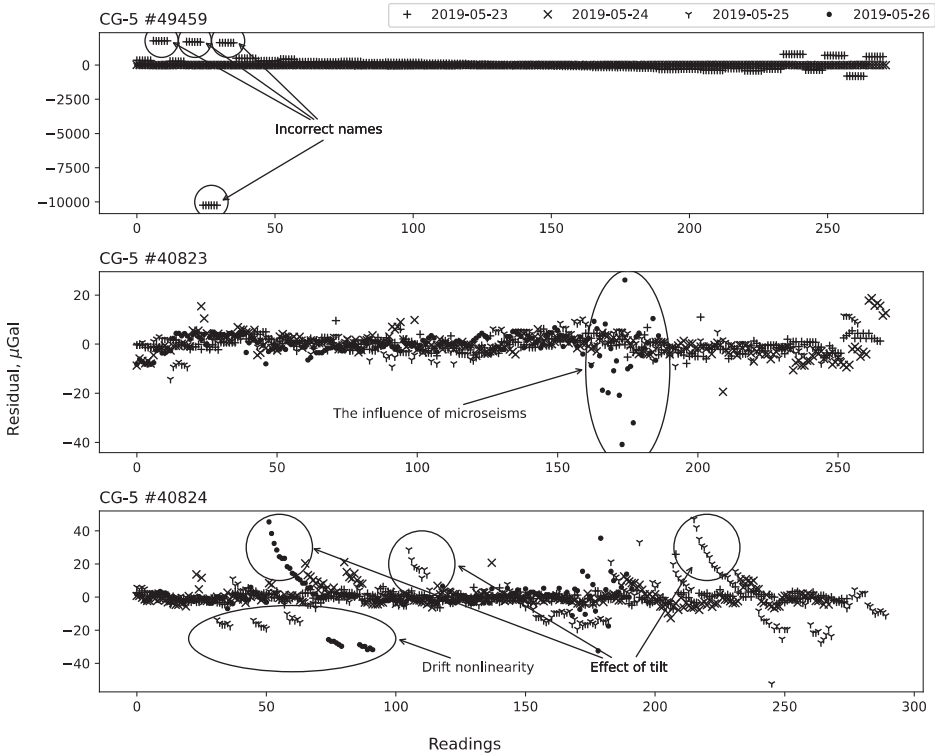


Fig. 3. Example of residuals in a least-squares adjustment: the deviations in the top plot indicate operator mistakes in station names, the deviations in the middle plot indicate the influence of seismic noise on the scatter of readings, the lower plot clearly shows the instability of the meter drift and its strong sensitivity to tilts.

wrong station name will deviate significantly from the mean level of residuals by several orders of magnitude. The upper plot illustrates evident outliers for gravity meter #49459. Following multiple cycles, all incorrect station names were located and rectified.

4.4. Dataset applications

Such studies can be found in the works [4–6]. Specifically, this dataset formed the basis of the study [7].

Limitations

The primary and only limitation of the Zhetygen calibration line is the lack of absolute gravity values at the stations and the middle range of change in gravity.

These limitations are extreme only if the gravity meters are used to develop gravimetric networks related to gravimetric systems of different states, for example. The first factor leads to different scaling, and the second one limits the use of devices on the calibration line, i.e., the calibration functions obtained on it cannot be used for extrapolation.

The limitations of the presented dataset are directly related to uncertainties arising from the influence of external conditions and the meter’s physical properties. The influence of external

conditions is well described, for example, in [2]. We will note only two factors: the influence of microseisms and the change in gravitational potential associated with the change in groundwater levels.

The influence of microseismic vibrations on the earth's surface is random and easily overcome by increasing the number of measurements. Since the recording frequency of the CG-5 gravity meter is 6 Hz, and the averaging in this observation program for one reading is 40 s, the standard deviations of individual readings are from 5 to 100 μGal , and the average value is 30 μGal , which is quite acceptable. The scatter associated with microseism in the second plot for gravimeter No. 40823 in Fig. 3.

The influence of groundwater is systematic and difficult to predict without additional research, such as drilling boreholes near gravity stations to measure the groundwater level during the measurements. It is an expensive and time-consuming process. The influence of the physical properties of the gravity meter sensor causes nonlinearity of the meter drift, which can lead to significant systematic errors. The step method in the presented dataset allows us to approximate the drift function by a polynomial with degree $n > 1$. Usually, degree $n = 2$ is used for approximation. The nonlinearity of the meter drift is visible from the residuals in plot 3 for gravity meter No. 40824. Also, this plot highlights the sequences of readings in the form of a curve resembling a hyperbola. This effect is most likely associated with the sensitivity of this meter to the influence of tilts during transportation. There is a detailed study on this effect in [8].

Ethics Statement

The authors have adhered to the ethical standards for publication in Data in Brief and affirm that the present study does not involve human participants, animal experimentation, or data sourced from social media platforms.

CRediT Author Statement

Roman Sermiagin: conceptualization, investigation, methodology, visualization, writing – original draft. **Yeraly Kalen:** data curation, resources, validation. **Nurgan Kemberbayev:** funding acquisition, project administration, supervision. **Khaini-Kamal Kassymkanova:** formal analysis, funding acquisition, project administration. **Nikolay Kosarev:** formal analysis, investigation, methodology, writing – review and editing. **Guzyaliya Mussina:** project administration, supervision, validation. **Assel Batalova:** project administration, supervision, validation.

Data Availability

Observation files of CG-5 gravity meters for the Zhetygen calibration line for five years (Original data) (Zenodo).

Acknowledgments

We extend our heartfelt appreciation to those who contributed to the execution of this research. Gratitude is extended to the scientific team involved in the project “Development of the Geoid Model of the Republic of Kazakhstan as the Basis of a Unified State Coordinate and Height System,” including representatives from Satbayev University, the Institute of Ionosphere, and GEOID LLP for their significant contributions throughout all phases of the article's development.

We express our gratitude to our colleagues at SPC Geoken LLP for granting access to essential resources and support in executing the experimental study. We like to recognize the significant contributions of our co-authors and colleagues who engaged in discussions regarding the results and assisted in refining the final version of the work.

We express our gratitude to Kanat Samarkhanov, Senior Researcher at Al-Farabi Kazakh National University, for his invaluable recommendations.

We express our gratitude to all anonymous reviewers for their helpful feedback and recommendations, which have greatly enhanced the quality of this publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that have or could be perceived to have influenced the work reported in this article.

APPENDIX A. Sample of Scintex CG-5 Data File

```
/
/      CG-5 SURVEY
/      Survey name:      geoken
/      Instrument S/N:    40824
/      Client:           geoken
/      Operator:         nurglassa
/      Date:             2023/12/11
/      Time:             08:31:09
/      LONG:             77.1000000 E
/      LAT:              43.7000000 N
/      ZONE:             43
/      GMT DIFF.:        -6.0
/
/      CG-5 SETUP PARAMETERS
/      Gref:              0.000
/      Gcall:             8400.551
/      TiltXS:            610.968
/      TiltYS:            659.323
/      TiltXO:            -101.453
/      TiltYO:            78.137
/      Tempo:            -0.130
/      Drift:             0.653
/      DriftTime Start:   08:31:12
/      DriftDate Start:   2023/12/11
/
/      CG-5 OPTIONS
/      Tide Correction:   YES
/      Cont. Tilt:       YES
/      Auto Rejection:    YES
/      Terrain Corr.:     NO
/      Seismic Filter:    YES
/      Raw Data:         NO
/
Line
/-----LINE-----STATION-----ALT-----GRAV-----SD-----TILTX-----TILTY-----TEMP-----TIDE-----DUR-----REJ-----TIME-----DEC.TIME+DATE-----TERRAIN-----DATE
0.0000000 10.0000000 0.0000 5874.502 0.018 0.0 -4.8 -2.23 -0.080 40 2 08:33:56 45240.35633 0.0000 2023/12/11
0.0000000 10.0000000 0.0000 5874.502 0.015 0.1 -4.8 -2.23 -0.079 40 0 08:34:45 45240.35689 0.0000 2023/12/11
0.0000000 10.0000000 0.0000 5874.501 0.015 0.2 -4.8 -2.23 -0.079 40 0 08:35:29 45240.35740 0.0000 2023/12/11
0.0000000 10.0000000 0.0000 5874.502 0.013 0.2 -4.7 -2.23 -0.079 40 0 08:36:13 45240.35791 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.027 0.008 5.4 2.6 -2.14 -0.076 40 0 08:51:14 45240.36832 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.027 0.007 6.4 3.0 -2.14 -0.076 40 2 08:52:03 45240.36889 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.030 0.008 6.8 2.6 -2.14 -0.076 40 0 08:52:47 45240.36940 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.030 0.011 7.3 2.5 -2.14 -0.076 40 0 08:53:31 45240.36990 0.0000 2023/12/11
0.0000000 1.0000000 0.0000 5894.126 0.016 9.5 0.9 -2.13 -0.071 40 0 09:17:14 45240.38635 0.0000 2023/12/11
0.0000000 1.0000000 0.0000 5894.125 0.018 10.4 0.4 -2.13 -0.071 40 0 09:18:03 45240.38691 0.0000 2023/12/11
0.0000000 1.0000000 0.0000 5894.127 0.014 11.5 0.3 -2.12 -0.070 40 0 09:18:47 45240.38742 0.0000 2023/12/11
0.0000000 1.0000000 0.0000 5894.127 0.017 11.8 0.0 -2.12 -0.070 40 0 09:19:31 45240.38793 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.027 0.012 3.1 -4.9 -1.94 -0.066 40 2 09:38:39 45240.40120 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.027 0.011 4.0 -4.8 -1.93 -0.066 40 0 09:39:28 45240.40176 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.025 0.009 4.9 -5.1 -1.93 -0.066 40 0 09:40:12 45240.40227 0.0000 2023/12/11
0.0000000 2.0000000 0.0000 5876.027 0.012 6.2 -5.4 -1.93 -0.066 40 0 09:40:56 45240.40278 0.0000 2023/12/11
...
0.0000000 2.0000000 0.0000 5758.974 0.010 4.6 -0.2 -4.43 -0.090 40 0 18:47:00 44427.78139 0.0000 2021/09/20
0.0000000 2.0000000 0.0000 5758.976 0.009 4.8 -0.2 -4.43 -0.090 40 0 18:47:48 44427.78194 0.0000 2021/09/20
0.0000000 2.0000000 0.0000 5758.977 0.010 5.0 -0.2 -4.42 -0.090 40 0 18:48:32 44427.78245 0.0000 2021/09/20
0.0000000 2.0000000 0.0000 5758.978 0.008 5.5 -0.2 -4.42 -0.090 40 3 18:49:16 44427.78296 0.0000 2021/09/20
0.0000000 2.0000000 0.0000 5758.975 0.019 5.3 -0.5 -4.42 -0.090 40 1 18:50:00 44427.78347 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.464 0.007 -2.5 -2.2 -4.31 -0.089 40 0 19:20:43 44427.80476 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.464 0.010 -2.5 -2.5 -4.26 -0.089 40 1 19:21:31 44427.80532 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.463 0.011 -2.5 -2.6 -4.21 -0.089 40 0 19:22:15 44427.80583 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.464 0.009 -2.4 -2.8 -4.17 -0.089 40 0 19:22:59 44427.80634 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.465 0.008 -2.5 -3.0 -4.13 -0.088 40 0 19:23:43 44427.80684 0.0000 2021/09/20
0.0000000 10.0000000 0.0000 5757.464 0.010 -2.4 -2.9 -4.10 -0.088 40 0 19:24:27 44427.80735 0.0000 2021/09/20
```

APPENDIX B. File Format Description

File format description.

Section	Parameter	Format	Description
Survey	Survey Name	String	Name of survey or object
	Instrument S/N	Integer	Serial number of meter
	Client	String	Name of Customer
	Operator	String	Name of Operator
	Date	YYYY/mm/dd	Date of Survey
	Time	HH:MM:SS	Time of Survey
	LONG	Float & E or W	Longitude
	LAT	Float & N or S	Latitude
	ZONE	Integer	UTM Zone
	GMT DIFF.	Float	Time difference in hours
Setup Parameters	Gref	Float	Reference gravity value
	Gcal1	Float	Calibration factor
	TiltxS	Float	Factor of X tilt
	TiltyS	Float	Factor of Y tilt
	TiltxO	Float	Offset of X tilt
	TiltyO	Float	Offset of Y tilt
	Tempco	Float	Coefficient of temperature
	Drift	Float	Drift factor
	DriftTime Start	HH:MM:SS	Time of start accept drift factor
	DriftDate Start	YYYY/mm/dd	Date of start accept drift factor
Options	Tide Correction	Boolean	Including tidal correction
	Cont. Tilt	Boolean	Continuous compensation
	Auto Rejection	Boolean	Automatic rejection of high frequency noise
	Terrain Corr.	Boolean	Correction of gravity for terrain effects
	Seismic Filter	Boolean	The seismic filter eliminates low frequency
Columns	Raw Data	Boolean	Storage of unprocessed 6 Hz data in memory
	LINE	Float	Line number
	STATION	Float	Station number
	ALT.	Float (m or °C)	Altitude or temperature
	GRAV.	Float (mGal)	Readings of gravity
	SD.	Float (mGal)	Standard Deviation
	TILTX	Float (arcsec)	X tilt value
	TILTY	Float (arcsec)	Y tilt value
	TEMP	Float (mK)	Temperature of sensor
	TIDE	Float (mGal)	Tide correction value
	DUR	Integer	Duration count
	REJ	Integer	Rejection count
	TIME	HH:MM:SS	Time of reading
	DEC.TIME+DATE	Float	Date and time in decimal
	TERRAIN	Float (mGal)	Terrain correction value
	DATE	YYYY/mm/dd	Date of reading

References

[1] CG-5 Operation Manual, CG-5 Scintrex Autograv System, 8th Edition, Scintrex Limited, Concord, Ontario Canada, 2012.

[2] W. Torge, *Gravimetry*, Wde Gruyter, Berlin; New York, 1989 ISBN: 9783110107029.

[3] C. Hwang, C.-G. Wang, L.-H. Lee, Adjustment of relative gravity measurements using weighted and datum-free constraints, *Comput. Geosci.* 28 (9) (2002) 1005–1015, doi:[10.1016/S0098-3004\(02\)00005-5](https://doi.org/10.1016/S0098-3004(02)00005-5).

[4] H. Cheraghi, J. Hinderer, S.A. Saadat, J.-D. Bernard, Y. Djamour, F. Tavakoli, S. Arabi, N.A. Kohan, Stability of the calibration of scintrex relative gravimeters as inferred from 12 years of measurements on a large amplitude calibration line in Iran, *Pure Appl. Geophys.* 177 (2) (2020) 991–1004, doi:[10.1007/s00024-019-02300-6](https://doi.org/10.1007/s00024-019-02300-6).

[5] S. Onizawa, Apparent calibration shift of the Scintrex CG-5 gravimeter caused by reading-dependent scale factor and instrumental drift, *J. Geodesy* 93 (9) (2019) 1335–1345, doi:[10.1007/s00190-019-01247-9](https://doi.org/10.1007/s00190-019-01247-9).

[6] M. Ukawa, K. Nozaki, H. Ueda, E. Fujita, Calibration shifts in Scintrex CG-3M gravimeters with an application to detection of microgravity changes at Iwo-tou caldera, Japan, *Geophys. Prospect.* 58 (6) (2010) 1123–1132, doi:[10.1111/j.1365-2478.2010.00869.x](https://doi.org/10.1111/j.1365-2478.2010.00869.x).

- [7] R. Sermiagin, N. Kemberbayev, K.-K. Kassymkanova, G. Mussina, M. Shkiyeva, N. Kosarev, K. Samarkhanov, A. Batalova, A. Rakhimzhanov, Y. Kalen, Selection of a calibration system for relative gravimeters and testing of the processing using the example of the Zhetygen calibration baseline in Kazakhstan, *Acta Geodaet. Geophys.* (2024), doi:[10.1007/s40328-024-00454-x](https://doi.org/10.1007/s40328-024-00454-x).
- [8] R. Reudink, R. Klees, O. Francis, J. Kusche, R. Schlesinger, A. Shabanloui, N. Sneeuw, L. Timmen, High tilt susceptibility of the Scintrex CG-5 relative gravimeters, *J. Geodesy* 88 (6) (2014) 617–622, doi:[10.1007/s00190-014-0705-0](https://doi.org/10.1007/s00190-014-0705-0).