Received: 14 March 2022 | Revised: 10 June 2022 | Accepted: 14 October 2022

DOI: 10.1002/gdj3.183

DATA ARTICLE

Geoscience Data Journal RMetS WILEY

Long time series of absolute gravity observations in Kulusuk, southeast Greenland

Olivier Francis

Faculty of Science, Technology and Medicine, University of Luxembourg, Esch-sur-Alzette, Luxembourg

Correspondence
Olivier Francis, Faculty of Science, Technology and Medicine, University of Luxembourg, Esch-sur-Alzette, Luxembourg.
Email: olivier.francis@uni.lu

Abstract

This report contains terrestrial absolute gravity measurements performed near the village of Kulusuk in southeast Greenland. It represents an exceptionally long time series of nearly two decades. The measurements began in July 1996 until July 2015. The station is located a few meters beside a permanent GNSS station. The final gravity values (g-values), more precisely the accelerations due to gravity, are listed along their associated uncertainties. A description of the station, a short explanation on the absolute gravimeter, and the data processing are presented.

KEYWORDS

absolute, glacial isostatic adjustment, gravimeter, gravity, Greenland

1 | DATASET

The dataset consists of 11 absolute gravity measurements taken over a span of 19 years in Kulusuk, east Greenland. The measurements were carried out with the state-of-the-art absolute gravimeter FG5 and FG5X from Micro-g LaCoste Inc. (for more information see FG5X Absolute Gravity Meters—Micro-g LaCoste or Niebauer et al., 2013). The site re-occupations happened the same month of the year between mid-July and beginning of August. The rationale is to measure gravity during the same time window in the seasons. Any annual signal (hydrology, snow) is sampled at or around the same phase of the cycle. In other words, it will considerably reduce the contribution of annual gravity effects on the long-term trend of the data. The dataset is used in the paper of van Dam et al. (2017). However, the g-values were not printed or even made public.

2 | DATA PROCESSING

Modern absolute gravimeters time the positions of a free-falling object (a retro-reflector) in a vacuum can. An atomic clock (a rubidium clock in general) provides the precise timing of the successive positions occupied by the object during its fall along the vertical. The precise positions are determined using the laser beam reflected by the falling retro-reflector directed into an interferometer. The high precise clock and stability of the laser (He-Ne stabilized laser) of at least 10^{-11} allow us to reach a precision of 1 ppb on absolute gravity observations (i.e., 10^{-9} of g equivalent to 10 nm.s^{-2}). An exhaustive error budget assessment is presented in Niebauer et al. (1995). The accuracy as specified by the manufacturer is 20 nm.s^{-2} (http://microglacoste.com/wp-content/uploads/2018/02/FG5-X-Brochure.pdf). Since 2007, the gravimeters involved in these measurements took part in International Absolute Gravimeter Comparisons to control that they operated properly (Francis et al., 2013; Jiang et al., 2011; Jiang et al., 2012, …).

Raw data from the absolute gravimeters consist of vectors of time and position of the falling object during the drops. To obtain the acceleration due to gravity, the nonlinear equation of motion is linearized with respect to the parameters (acceleration, initial velocity, and position) by fixing the value of the vertical gravity gradient (VGG). Then, these parameters are estimated by a least-square adjustment on the raw data.

The data processing follows the protocol adopted during absolute gravimeters comparisons at the 'Bureau International des Poids et Mesures' in Sèvres (Francis & van Dam, 2003). Geophysical corrections are applied to the raw gravity data: earth tides using modeled tidal parameters (see details in van Dam et al., 2017), atmospheric pressure effect using a constant admittance, and the polar motion effect using pole positions from the International Earth Rotation Service (http://hpiers.obspm.fr).

FIGURE 1 FG5-216 absolute gravimeter at the gravity site of Kulusuk, southeast Grenland. The permanent GNSS antenna is visible in the background. The blue shed is equipped with electric power and hosts the GNSS receiver.

In addition, the value of VGG is required to linearize the equation of motion of the falling mass inside the gravimeter. It is also needed to transfer the g-value from the reference height (specific to each gravimeter) around 1.38 m to the desired height (in general at the floor level). In this paper, we provide the g-values at 1.00 m. The determination of the VGG is obtained by using relative gravity measurements above the benchmark taken at two different levels of a stable tripod. These measurements were carried out on July 24, 1999, with a Scintrex CG-3 (https://scintrexltd.com/support/product-manuals/cg3-manual/). We obtained a VGG value of $-0.3873 \pm 0.0019\,\text{nm.s}^{-2}\,\text{m}^{-1}$.

The same version of the g-soft 9.120423 software from Micro-g LaCoste Inc. was applied to all the data (from 1996 to 2015) to ensure consistent data processing.

3 | GRAVITY STATION IN KULUSUK

The absolute gravity station is located on top of an outcrop 10 m northeast from the hotel Kulusuk (Figure 1). This hotel is close the shoreline at 1 km north of the nearby Kulusuk International Airport. A benchmark was placed and lies in between the hotel and the concrete pillar of the permanent GNSS antenna. A few meters away, there is a small shed equipped with electricity hosting the GNSS

TABLE 1 Absolute gravity data at the Kulusuk station in southeast Greenland

Date	Absolute gravity, /nm.s^{-2}	Uncertainty, /nm.s^{-2}	Gravimeter	Applied offset, /nm.s^{-2}
August 2, 1996	9,823,371,824	36	FG5#102	0
July 30, 1997	9,823,371,806	58	FG5#102	0
July 27, 1998	9,823,371,940	35	FG5#111	0
July 28, 1999	9,823,371,943	35	FG5#111	0
July 19, 2000	9,823,371,934	28	FG5#111	0
July 19, 2003	9,823,371,905	28	FG5#216	30
July 23, 2007	9,823,371,831	14	FG5#216	17
July 16, 2008	9,823,371,796	23	FG5#216	17
July 19, 2010	9,823,371,772	28	FG5#216	0
July 16, 2012	9,823,371,743	20	FG5X#216	0
July 19, 2015	9,823,371,721	13	FG5X#216	0

Note: The g-values are given at the height of 1 m above the floor. The entries in column 5 are the instrument offsets that have been applied to the data in column 2. These offsets were determined when the instruments took part in the International Comparisons of Absolute Gravimeters.

The FG5#102 and #111 belong to the National Geodetic Service of the National Oceanic and Atmospheric Administration (NGS-NOAA). The FG5#216 and its upgraded version FGX-216 belong to the University of Luxembourg.

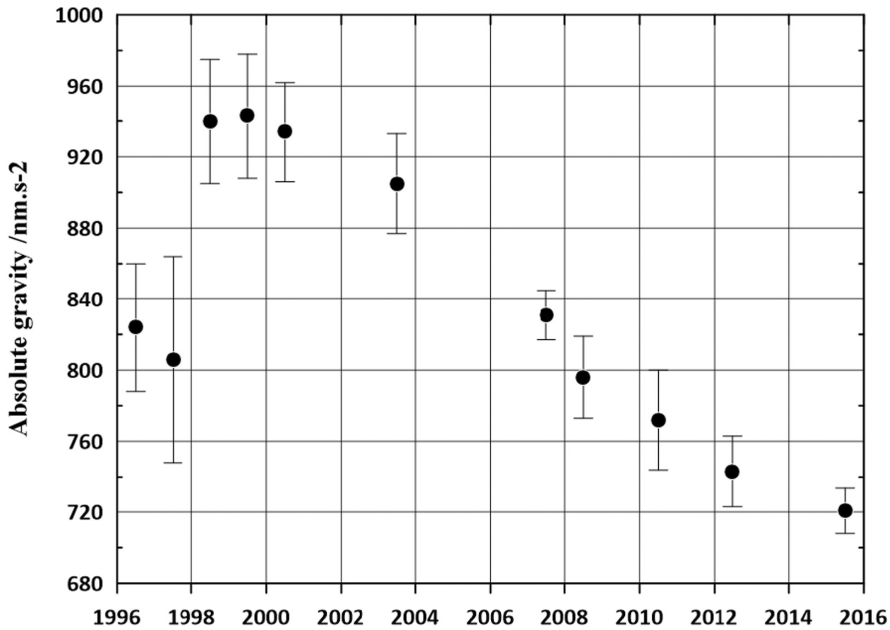

FIGURE 2 Absolute gravity measurements in Kulusuk, southeast Greenland

receiver. The GPS coordinates of the station are: latitude: 65.57760, longitude: −37.15632, and elevation above sea level: 13.90 m.

4 | ABSOLUTE GRAVITY OBSERVATIONS

The g-values are displayed in Table 1 with their associated uncertainty and displayed in Figure 2. The latter is calculated as the standard deviation (1 sigma) of the sets' average.

The systematic uncertainty of 20 $nm.s^{-2}$ as specified by the manufacturer of the FG5 is not included in the presented uncertainties. That contribution should be added to the uncertainty budget if the user is interested in the absolute values of the acceleration due to gravity. On the other hand, if gravity changes in time are investigated, the systematic uncertainty can be ignored as it will be canceled out in calculating differences. For the FG5-216 and FG5X-216, this systematic error has been the same and constant over time and verified during International Comparisons of Absolute Gravimeters.

In general, a measurement session lasts 48 hr with a set per hour containing 100 drops taken every 10 s.

The large gravity offset between 1997 and 1998 is not related to the switch to another gravimeter. It is a permanent gravity change caused by the construction of the Kulusuk hotel close to the gravity site (van Dam et al., 2017).

ACKNOWLEDGEMENTS

The gravity campaigns were funded by a NASA project (1996-2000), by the European Center for Geodynamics and Seismology in Luxembourg (2003), and finally by the Université du Luxembourg (2007–2015). The author is grateful to Ing. Gilbert Klein from the Université du Luxembourg who took part in several trips to assist during the field measurements.

OPEN RESEARCH BADGES

This article has earned an Open Data badge for making publicly available the digitally-shareable data necessary to reproduce the reported results. The data is available at [https://osf.io/t6zse/]. Learn more about the Open Practices badges from the Center for Open Science: https://osf.io/tvyxz/wiki.

ORCID

Olivier Francis https://orcid.org/0000-0002-3743-3630

REFERENCES

Francis, O., Baumann, H., Volarik, T., Rothleitner, C., Klein, G., Seil, M. et al. (2013) The European Comparison of Absolute Gravimeters 2011 (ECAG-2011) in Walferdange, Luxembourg: results and recommendations. *Metrologia*, 50(3), 257–268. https://doi.org/10.1088/0026-1394/50/3/257

Francis, O. & van Dam, T.M. (2003) Processing of the Absolute data of the ICAG01. *Cahiers du Centre Européen de Géodynamique et de Séismologie*, 22, 45–48.

Jiang, Z., Francis, O., Vitushkin, L., Palinkas, V., Germak, A., Becker, M. et al. (2011) Final report on the Seventh International Comparison of Absolute Gravimeters (ICAG 2005). *Metrologia*, 48, 246–260. https://doi.org/10.1088/0026-1394/48/5/003

Jiang, Z., Pálinkáš, V., Arias, F.E., Liard, J., Merlet, S., Wilmes, H. et al. (2012) The 8th International Comparison of Absolute Gravimeters 2009: the first Key Comparison (CCM.G-K1) in the field of absolute gravimetry. *Metrologia*, 49(6), 666–684. https://doi.org/10.1088/0026-1394/49/6/666

Niebauer, T.M., Billson, R., Schiel, A., van Westrum, D. & Klopping, F. (2013) The self-attraction correction for the FG5X absolute gravity meter. *Metrologia*, 50(1), 1–8. https://doi.org/10.1088/0026-1394/50/1/1

Niebauer, T.M., Sasagawa, G.S., Faller, J.E., Hilt, R. & Klopping, F. (1995) A new generation of absolute gravimeters. *Metrologia*, 32(3), 159–180. https://doi.org/10.1088/0026-1394/32/3/004

van Dam, T., Francis, O., Wahr, J., Khan, S.A., Bevis, M. & Broeke, M.R.V.D. (2017) Using GPS and absolute gravity observations to separate the effects of present-day and Pleistocene ice-mass changes in South East Greenland. *Earth and Planetary Science Letters*, 459, 127–135. https://doi.org/10.1016/j.epsl.2016.11.014

How to cite this article: Francis, O. (2023) Long time series of absolute gravity observations in Kulusuk, southeast Greenland. *Geoscience Data Journal*, 10, 485–488. Available from: https://doi.org/10.1002/gdj3.183