WETCAG-2024

EURAMET Key Comparison of Absolute Gravimeters EURAMET.M.G-K2.2023 and Additional Comparison

(EURAMET project No. 1603)

Wettzell (Germany), May/June 2024

Coordinating institute

VUGTK/RIGTC
Research Institute of Geodesy, Topography and Cartography
Czechia

Organization

Federal Agency for Cartography and Geodesy (BKG)

Germany

Technical Protocol

May 14, 2024

From Version March 5, 2024 to Version May 14, 2024

Tab. 2 has to be modified for instrumental reasons of AG-6.

IMPORTANT DEADLINES

We would like to present the results of the comparison as soon as possible. For that, we count on your collaboration to respect the different deadlines:

March 2, 2024	Approbation of the Technical Report by all participants.
March 15 2024	Deadline for sending the completed form of **Annex A** to agrav@bkg.bund.de .
May - June 2024	Comparison at the Geodetic Observatory Wettzell.
August 2, 2024	Presentation of the results by the participants to agrav@bkg.bund.de . **(Annexes B and C)**.
August 23, 2024	Results are confirmed by participants.
November 1, 2024	Draft A (confidential) presented to the participants.
December 13, 2024	Deadline for comments on Draft A.
February 2025	Draft B (in public form) presented to the participants.

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1. Introduction

The EURAMET Key Comparison of Absolute Gravimeters EURAMET.M.G-K2.2023 and Additional Comparison (WETCAG-2024) will be conducted at the Geodetic Observatory Wettzell (Germany) in May/June 2024. The main purpose is to provide a link to the CCM.G-K2.2023 Key Comparison at Table Mountain Geophysical Observatory (TMGO), Boulder, Colorado, USA (Newell et al. 2024) for EURAMET members and associates and for the validation of the calibration and measurement capability (CMCs) published in the Key Comparison Data Base (KCDB) of BIPM. The additional comparison will allow to assess absolute gravimeters operated by European institutions in geodesy and geosciences and is an essential contribution to the upcoming International Terrestrial Gravity Reference Frame (ITGRF) of IAG.

This document is based on the joint strategy of the Consultative Committee for Mass and related quantities (CCM) and Commission 2 "Gravity Field" of the International Association for Geodesy (IAG) of 2014 (Marti et al. 2014), which coordinates and harmonizes the activities in geodesy and metrology. In accordance with this strategy, the WETCAG-2024 comparison is organized as a Key Comparison (KC) linked to the CCM.G-K2.2023 by means of joint participants. By this, the comparison will document compatibility, including with CMCs, at highest level of accuracy.

Only National Metrology Institutes (NMIs) that are signatories of the CIPM Mutual Recognition Arrangement (CIPM MRA), and laboratories officially designated by those institutes (DIs), can participate in the KC. The measurements of absolute gravimeters operated by these institutions directly contribute to the definition of Key Comparison Reference Values (KCRVs). An Additional Comparison is organized simultaneously for the other participants not being EURAMET members or associates. Main objectives of the comparison are the validation of published CMCs[1] and the realization of the International Terrestrial Gravity Reference Frame (Wziontek et. al, 2021).

WETCAG-2024 is an RMO[2] Key Comparison registered as EURAMET project 1603[3].

The comparison is organized in accordance with the CIPM MRA-G-11 of the Consultative Committee on Mass and Related Quantities (CCM) (CIPM 2021). Therefore, only the degree of equivalence of gravimeters included in the Key Comparison will be published in the Key Comparison Data Base (KCDB) of BIPM[4].

The results of non-NMI/DIs will be included as appendix of the Final Report in Metrologia's Technical Supplement.

The Key Comparison of Absolute Gravimeters EURAMET.M.G-K2.2023 as well as the related Additional comparison will be coordinated by Dr. Vojtech Pálinkáš of the Research Institute of Geodesy, Topography and Cartography, v.v.i. (VÚGTK), Czechia (VÚGTK) as pilot and conducted by the German Federal Agency for Cartography and Geodesy (BKG)

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[1] https://www.bipm.org/kcdb/cmc/quick-search?includedFilters=&excludedFilters=&page=0&keywords=gravity

[2] Regional Metrology Organization

[3] https://www.euramet.org/technical-committees/tc-projects/details/project/key-comparison-of-absolute-gravimeters

[4] https://www.bipm.org/kcdb/comparison?id=1906

at its Geodetic Observatory Wettzell (GOW) close to the city of Bad Kötzting (Germany) in May / June 2024.

Dr. Hartmut Wziontek, Jan Müller and Dr. Reinhard Falk (all of BKG) have agreed to serve as the local organizing committee. Dr. Thomas Klügel of the GOW will support the activities in Wettzell.

2. Participants

The list of the participants is given in Tables 1a and 1b. In total, 17 absolute gravimeters from 15 institutions will take part in the comparisons including 4 different types of instruments.

The link to CCM.G-K2.2023 will be provided by 3 absolute gravimeters.

The superconducting gravimeter SG-030 (Fig.2) is continuously recording during the period of the comparison in the new gravity building in Wettzell. This record will be used to determine residual temporal gravity variations to link (in time domain) all measurements of WETCAG-2024.

Figure 1. Comparison site during EURAMET.M.G-K3 in 2018

Figure 2. GWR SG030 of BKG is registering temporal gravity variations at pillar WET_GA continuously since 2010

Table 1a. List of the participants of WETCAG-2024 Comparison

(* NMI or Designated Institute, ** participant of CCM.G-K2.2023)

Country	Institution	Gravimeter	*	**	Alias	Operator(s)	e-mail
EURAMET.M.G-K2.2023							
Czechia	Research Institute of Geodesy, Topography and Cartography, v.v.i. (VÚGTK), Zdiby	FG5X-251/HS5	YES	YES	**AG-10**	Vojtech Pálinkáš, JaKub Kostelecký	vojtech.palinkas@pecny.cz jakub.kostelecky@pecny.cz
Finland	Finnish Geospatial Research Institute (FGI), National Land Survey of Finland (NLS), Helsinki	FG5X-221	YES	YES	**AG-1**	Mirjam Bilker-Koivula	mirjam.bilker-koivula@maanmittauslaitos.fi
France	LNE- SYRTE, Paris (EOST, Strasbourg)	FG5X-206	YES	NO	**AG-15**	Sébastien Merlet, Jean-Daniel Bernard	Sebastien.Merlet@obspm.fr jd.bernard@unistra.fr
Germany	PTB, Braunschweig	FG5X-263	YES	YES	**AG-2**	Christian Rothleitner	christian.rothleitner@ptb.de
Italy	Istituto Nazionale di Ricerca Metrologica (INRIM), Torino	IMGC-02	YES	NO	**AG-16**	Andrea Prato, Alessio Facello	a.prato@inrim.it a.facello@inrim.it
Switzerland	METAS, Wabern	FG5X-209	YES	NO	**AG-11**	Henri Baumann	Henri.Baumann@metas.ch

Table 1b. List of the participants of WETCAG-2024 Additional comparison

(* NMI or Designated Institute, ** participant of CCM.G-K2.2023,

*** FG5-101, FG5-211, FG5-227, FG5-238 and FG5X-233 of non NMI/DI participated in the additional comparison related to CCM.G-K2.2023)

Country	Institution	Gravimeter	*	**	Alias	Operator(s)	e-mail
Additional Comparison							
Germany	GFZ German Research Centre for Geosciences, Dept. Hydrology, Potsdam	AQG-B02	NO	NO	AG-14	Marvin Reich	mreich@gfz-potsdam.de
Germany	Federal Agency for Cartography and Geodesy (BKG), Leipzig	FG5-101 FG5-227 FG5-301	NO	YES*** YES*** NO	AG-17 AG-9 AG-4	André Gebauer, A. Lothhammer, Erik Brachmann	andre.gebauer@bkg.bund.de alexander.lothhammer@bkg.bund.de erik.brachmann@bkg.bund.de
Italy	e-geos, Matera	FG5-218	NO	NO	AG-12	Iacovone Domenico	domenico.iacovone@e-geos.it
Italy	National Institute of Geophysics and Volcanology (INGV), Rome	FG5-238	NO	YES***	AG-6	Filippo Greco, Alfio Alex Messina	filippo.greco@ingv.it

Country	Institution	Gravimeter	*	**	Alias	Operator(s)	e-mail
Netherlands	Delft University of Technology, Delft	FG5X-234	NO	NO	**AG-7**	René Reudink	R.H.C.Reudink@tudelft.nl
Poland	Institute of Geodesy and Cartography (IGiK), Warszawa	A10-20 or AQG-B07	NO	NO	**AG-3**	Przemyslaw Dykowski, Adam Ciesielski	przemyslaw.dykowski@igik.edu.pl
Slovakia	Slovak University of Technology, Bratislava	FG5X-247	NO	NO	**AG-8**	Juraj Janák, Juraj Papčo	juraj.papco@stuba.sk juraj.janak@stuba.sk
Spain	Instituto Geográfico Nacional, Madrid	FG5-211	NO	YES***	**AG-13**	Arturo Villar García, Chaves Ruiz Felix Manuel	avillarg@mitma.es fmchaves@mitma.es
Sweden	Lantmäteriet, Gävle	FG5X-233	NO	YES***	**AG-5**	Andreas Engfeldt	Andreas.Engfeldt@lm.se

3. Measurand

The measurand is the mean acceleration of free-fall at the reference height corrected for Earth tides, atmospheric and polar motion effects on gravity. Corrections are made in compliance with the ITGRS 2020 conventions (Wziontek et al., 2021) and IAG Resolution of 2023 (IAG 2023).

Corrections are in particular

- The effect of the Earth tides in the zero- tide concept.
- The effect of atmospheric mass changes using a constant admittance factor of -0.3 µGal/hPa on the difference between the normal air pressure and measured air pressure at the station.
- The polar motion effect with respect to Earth orientation in the ITRS (International Terrestrial Reference System).

The geodetic coordinates and elevation of the measuring sites (stations), as well as the observed tidal parameters are listed in Annex D.

The polar motion coordinates are published by the IERS at https://www.iers.org/IERS/EN/DataProducts/EarthOrientationData/eop.html

The start and end time of the measurement of the observations which are contributing to the measurement shall be reported.

All relevant information concerning the measurements and corrections will be made available to the participants after the comparison (Draft A, B and C).

The gravity changes along the vertical (vertical gravity gradient, VGG) at each comparison site is given in Annex D.

The participants have to provide the value of the VGG in Annex B, which was used within the solution of the equation of motion and for transferring *g* to the measurement height. To avoid any possible confusion, we recommend reporting *g* in the effective instrumental height (distance between benchmark and the effective position of free-fall, ≈1.21 m for the FG5 and ≈1.27 m for the FG5X) (Wziontek et al., 2021), where *g* is invariant on the VGG used in the equation of motion.

4. Methods and program of measurement

Details concerning the instrumentation and methods of the absolute measurements should be described by each participant (Annex A).

A four-site gravity network is proposed for the measurements within WETCAG-2024. Each gravimeter should measure at least at two, in general at three gravity sites.

The site reservation schedule shown in Tab. 2 includes the option of measuring at all 4 pillars, which is **not mandatory.**

The measurement schedule of the comparison will be further tuned according to the actually possible number of site occupations in order to optimize the comparison performance. It may also become necessary in the event of cancellation of participation. However, this only requires a change of the alias AG numbers within the week groups.

A particular gravimeter can occupy the given site in Table 2 within 23 hours, starting at 11 am of the specified date and ending at 10 am of the next day (the remaining one hour is for gravimeter movements).

The comparison will be organized in five sessions, four of them with measurements starting on Monday. Therefore, the measurements at three sites should be finished on Thursday. The measurements of the first session in the last week of May will start on Tuesday, May 21nd and ends on Friday May 24, due to the holiday on Monday, May 20. In case of instrumental troubles, the local organizer can permit an additional re-measurement.

Access to the comparison site outside of the regular observation times can be provided upon request.

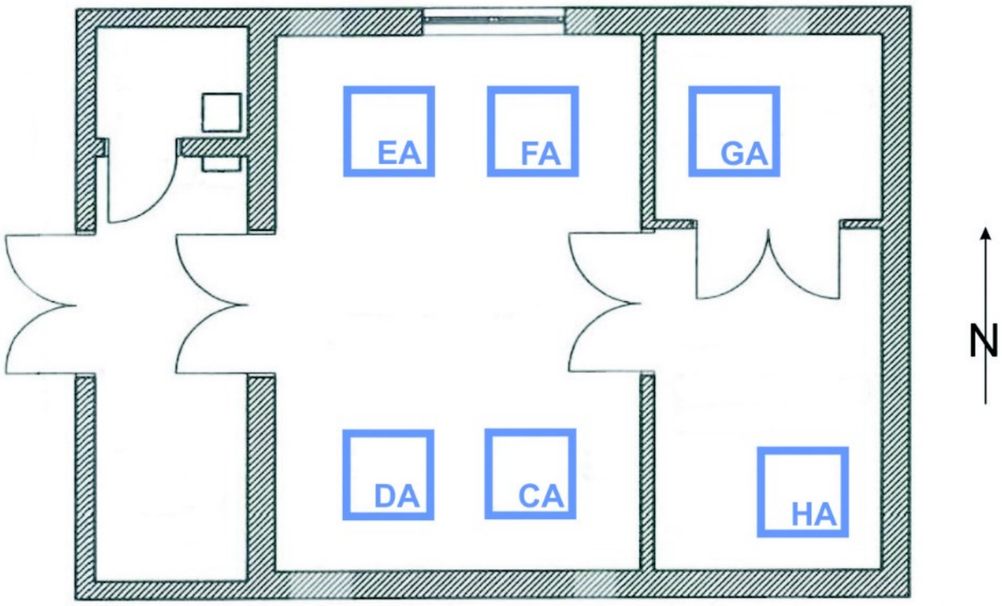

Figure 1. Sketch of the gravity laboratory of BKG at GOW, the pier G is occupied by the SG030 and pier H will be not used in WETCAG-2024. Each pier is equipped in its center with a benchmark, which defines the position A of this pier. The site codes for this comparison are CA, DA, EA and FA.

Table 2. **Site reservation schedule**

A particular gravimeter can occupy the given site within 23 hours,
starting at 11 am of the specified date and ending at 10 am of the next day.

(Instruments participating in the key comparison are marked yellow.)

weekday	date month/day/year	WET_CA	WET_DA	WET_EA	WET_FA
Tuesday	5/21/2024	AG-1	AG-2	AG-3	AG-4
Wednesday	5/22/2024	AG-4	AG-1	AG-2	AG-3
Thursday	5/23/2024	AG-3	AG-4	AG-1	AG-2
Friday	5/24/2024	AG-2	AG-3	AG-4	AG-1
Monday	5/27/2024	AG-5		AG-7	AG-8
Tuesday	5/28/2024	AG-8	AG-5		AG-7
Wednesday	5/29/2024	AG-7	AG-8	AG-5	
Thursday	5/30/2024		AG-7	AG-8	AG-5
Monday	6/03/2024	AG-9	AG-10	AG-11	AG-12
Tuesday	6/04/2024	AG-12	AG-9	AG-10	AG-11
Wednesday	6/05/2024	AG-11	AG-12	AG-9	AG-10
Thursday	6/06/2024	AG-10	AG-11	AG-12	AG-9
Monday	6/10/2024	AG-17		AG-6	
Tuesday	6/11/2024		AG-17		AG-6
Wednesday	6/12/2024	AG-6		AG-17	
Thursday	6/13/2024		AG-6		AG-17
Monday	6/17/2024	AG-13	AG-14	AG-15	AG-16
Tuesday	6/18/2024	AG-16	AG-13	AG-14	AG-15
Wednesday	6/19/2024	AG-15	AG-16	AG-13	AG-14
Thursday	6/20/2024	AG-14	AG-15	AG-16	AG-13

5. Data report

All participants must provide the absolute measurement results for every measured site (pier) in the electronic table format given for Annex B. The operators are responsible for processing their own gravity data, including the application of corrections for all known systematic instrumental effects.

The pilot laboratory will be responsible for reducing the submitted gravity values to a common height (1.25 m) using the vertical gravity gradients at each pier from annex D and to apply corrections for residual temporal gravity variations.

It would be very much appreciated, if all participants would provide the single drop data as we are planning an alternative processing based on the registered signal of the superconducting gravimeter SG-030. This information is voluntary.

These data can be provided by ftp using the details given in table 3. Please create a separate directory for each gravimeter and name it according to type and serial number, e.g. FG5X-251.

Table 3. **Data transfer information**

FTP server	user	pwd
gopoc.pecny.cz	ecag2024	gace2024

6. Uncertainty evaluation

"*A result from a participant is not considered complete without its associated measurement uncertainty; measured values are not included in the draft report unless they are accompanied by a measurement uncertainty supported by a complete measurement uncertainty budget. Measurement uncertainties are estimated following the guidance given in the technical protocol.*" (CIPM 2021).

Measurement uncertainties should be evaluated by **each participant** based on principles laid out in JCGM (2008). In Annex B, it is mandatory to report the **total/combined measurement uncertainty** (u_c) and the **instrumental part of this uncertainty** (u_{ins}) with the remaining uncertainty $u_{geo} = \sqrt{u_c^2 - u_{ins}^2}$ related to the contribution of corrections from temporal gravity variations (so called "geophysical effects": tides, atmosphere, polar motion). This procedure is required due to the fact that corrections (with associated uncertainty) due to residual temporal gravity variations will be applied to the reported g-values, based on the record of the superconducting gravimeter.

An example of calculation of uncertainty with complete uncertainty budget can be found in Annex C. Reporting the complete **uncertainty budget** for a particular gravimeter within Annex C is **mandatory only for KC participants**. Participants of the additional comparison are welcomed to provide any information on the uncertainty estimation (e.g. contributions of principal components of their measurement uncertainty) within Annex C.

In line with the above, principal components of the measurement uncertainty budget for gravimeters can be divided into instrument uncertainty and the uncertainty of models for correction of the temporal gravity variations to reach the consensus value of gravity acceleration (Wziontek et al. 2021):

1. uncertainty budget of the instrument that includes for gravimeters based on laser interferometry the following principal components (some of them might be site dependent):
    - Laser frequency
    - Rb-clock frequency
    - Corner cube rotation
    - Coriolis effect
    - Inhomogeneous magnetic field, magnetic gradient
    - Temperature changes, thermal gradient
    - Residual air pressure
    - Misalignments in verticality
    - Glass wedges
    - Diffraction effects
    - Floor and inertial mass recoil
    - Phase shifts in fringe counting and timing electronics, signal distortion
    - Dispersion effects
    - Air gap modulation
    - Reference height determination
    - Apparatus gravity attraction effect
    - Choice of the evaluation interval for fringes
    - Setup of the gravimeter
    - Interferometer alignment
    - Measurement repeatability

2. uncertainty of components for correcting the temporal gravity variations to reach the consensus value of gravity acceleration:
    - Barometer (sensor) error
    - Atmospheric effect modelling (e.g. single admittance approach)
    - Solid Earth tide and ocean tide modelling
    - Polar motion correction

An estimate of the measurand *Y*, denoted by g (gravity acceleration in our case), is obtained from input quantities X_i (i=1…N) using input estimates x_i as $g = f(x_i)$. Considering known systematic effects of input estimates Δx_i and uncertainties in the form of standard deviation s_i (type A) and a_i (type B) are expressed:

- standard uncertainty:

  note: k_a depends on the type of statistical distribution (2 for U distribution, 3 for rectangular, 6 for triangular, etc.)

$$u^2(x_i) = s_i^2 \vee \frac{a_i^2}{k_a} \tag{1}$$

- sensitivity coefficients:

$$c_i = \frac{\partial f}{\partial x_i} \tag{2}$$

- single gravity error for known systematic effect:

$$\Delta g_i = c_i \cdot \Delta x_i \tag{3}$$

- variances:

$$u^2(g_i) = c_i^2 u^2(x_i) \tag{4}$$

- combined standard uncertainty:

$$u_c(g) = \sqrt{\sum_{i=1}^{n} u^2(g_i)} \tag{5}$$

- sum of known systematic gravity errors:

$$\Delta g = \sum_{i=1}^{n} \Delta g_i \tag{6}$$

- effective degree of freedom, according to the Welch-Satterthwaite formula:

$$\nu_{eff} = \frac{u_c^4(g)}{\sum_{i=1}^{n} \frac{u_i^4(g)}{\nu_i}} \tag{7}$$

- coverage factor (p=level of confidence):

$$k = f(\nu_{eff}, p) \tag{8}$$

- expanded combined standard uncertainty:

  note: JCGM (2008) recommends to apply corrections for known systematic effects. If corrections Δg_i^{NA} are not applied it should be taken into account (see F.2.4.5 in JCGM (2008)) by enlarging the expanded uncertainty.

$$U_c(g) = k \cdot u_c(g) + \left|\sum \Delta g_i^{NA}\right| \tag{9}$$

- relative expanded standard uncertainty:

$$U_{rel}(g) = \frac{U_c(g)}{g} \tag{10}$$

All participants are requested to estimate (e.g. based on their long-term experience with the gravimeter) the long-term reproducibility of the measurements. It can be understood as a parameter which describes the degree of consistency of an AG after several years.

The reproducibility is defined as a closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of measurement. It includes random errors (e.g. setup error, errors of applied corrections for geophysical effects) but also errors which may cause systematic effects over a few months (e.g. in connection with the interferometer alignment, such as collimation or fringe size/distortion effect). This information would be necessary to separate the systematic and stochastic parts of the uncertainties and by this to achieve a more realistic error propagation.

7. Frequency measurements during the comparison

The GOW enables the determination of Rb-clock frequency by providing a 10 MHz reference frequency of the observatories time system. The frequency difference is measured by a Stanford Research SR620 frequency counter. For this comparison a period of about at least 3 hours should be scheduled.

8. Results elaboration and link to the CCM.G-K2.2023

The results will be processed as proposed by Palinkas et al. (2021) as an KCN type comparison and also as an ICN type to determine the comparison reference values (CRV) and gravimeter biases. For testing robustness, different solutions will be compared according to the definition of constraints to link the results to CCM.G-K2.2023 in 2023 by

1) the degree of equivalence (DoE) of AGs operated by NMI (the official KCN solution),
2) the DoE of all AGs participating in both comparisons,

and also as the ICN solution, without the link to CCM.G-K2.2023.

The main outcome of the comparison, DoEs of the gravimeters, will be calculated from the difference between the gravimeter measurements and the CRVs.

The Pilot Laboratory will process the data in different ways and the results will be presented in the Draft A report. Consequently, the participants will decide which will be the more appropriate method and it will be implemented in the Draft B report.

Since the comparison strive for a blind test type of measurement, participants cannot communicate their results, neither to other participants nor officially on any other way before the issue of the Draft A. Once the draft B of the report on KC is published all the results of the comparison will be made public.

9. Lodging and travel details

The Geodetic Observatory Wettzell (GOW) is situated in the Bavarian forest, a popular German vacation area.

Address:
Observatorium Wettzell, Sackenrieder Straße 25, 93444 Bad Kötzting
Fon : +49 (0) 99 41 603 - 0
Fax : +49 (0) 99 41 603 - 222

Several hotels or guest houses are available within 10 km from the comparison site.

Lodging information for the city of Bad Kötzting you will find
https://bad-koetzting.de/tourismus/urlaub/ihre-gastgeber.

BKG will give support for room booking on request. (Prices per day vary between 48 € and 84 €.)

Travel information to the Geodetic Observatory Wettzell are available
https://www.bkg.bund.de/EN/About-BKG/Addresses/Wettzell/wettzell.html.

During the week (Monday – Friday) lunch will be provided at the Geodetic Observatory Wettzell on request.

Each participating institute is responsible for its own costs for the measurements.

10.References

Marti, U, Richard, Ph, Germak, A, Vitushkin, V, Pálinkáš V, Wilmes H (2014) *CCM-IAG Strategy for Metrology in Absolute Gravimetry.* http://www.bipm.org/wg/CCM/CCM-WGG/Allowed/2015-meeting/CCM_IAG_Strategy.pdf

JCGM Working Group 1 of the Joint Committee for Guides in Metrology (2008) *Evaluation of measurement data – Guide to the expression of uncertainty in measurement (GUM).* JCGM 100:2008

Falk R, Pálinkáš V, Wziontek H, Rülke A, Val'ko M, Ullrich C, Butta H et al. (2020) *Final report of EURAMET.M.G-K3 regional comparison of absolute gravimeters*. Metrologia 57:07019 , https://iopscience.iop.org/article/10.1088/0026-1394/57/1A/07019

IAG (2023) *Resolution for the International Terrestrial Gravity Reference System (ITGRS)*, https://www.iag-aig.org/doc/651bd7f2e3cbf.pdf

CIPM (2021) *Measurement comparisons in the CIPM MRA: Guidelines for organizing, participating and reporting* CIPM MRA-G-11 Version 1.1

Pálinkáš, V., Wziontek, H., Vaľko, M. et al. (2021) *Evaluation of comparisons of absolute gravimeters using correlated quantities: reprocessing and analyses of recent comparisons*. J Geod 95, 21. https://doi.org/10.1007/s00190-020-01435-y

Wziontek, H., Bonvalot, S., Falk, R. et al. : *Status of the International Gravity Reference System and Frame*. J Geod 95, 7 (2021). https://doi.org/10.1007/s00190-020-01438-9

Newell, D. Westrum, D. et al.: *Draft B/final report of CCM.G-K2.2023*, in preparation

Annex A - Description of the absolute gravimeter

Annex B - Report of measurement results

Annex C - Example of calculation of uncertainty

Annex A, B and C are documented in the spreadsheet

WETCAG-2024_AnnexABC.xlsx

Annex D - Parameters of the Wettzell Gravity Laboratory

Name of the station: Wettzell (WET)

Bench mark designations: WET_CA, WET_DA, WET_EA, WET_FA

Latitude: 49.14483 North Longitude: 12.87631 East Altitude: 606.60 m

Table D.1 Gradient information (Falk et.al, 2020)

Site	Vertical gravity gradient µGal /m
WET_CA	-328.7
WET_DA	-330.1
WET_EA	-319.5
WET_FA	-319.9

Table D.2 Observed tidal parameters (analyzing observation results of GWR-SG030 superconducting gravimeter, processing E. Antokoletz (BKG), 2023)
This table is provided also separately as a file wet2023s.par .

```
TIDALPARAM=  0.000000  0.000010   1.00000    0.0000 long
TIDALPARAM=  0.000011  0.003426   1.16000    0.0000 SA
TIDALPARAM=  0.004709  0.010952   1.16000    0.0000 SSA
TIDALPARAM=  0.025812  0.044652   1.14336    0.3776 Mm
TIDALPARAM=  0.060132  0.080797   1.14126    0.6868 Mf
TIDALPARAM=  0.096423  0.249951   1.15426   -0.5090 Mtm
TIDALPARAM=  0.721500  0.906315   1.14919   -0.2069 Q1
TIDALPARAM=  0.921941  0.940487   1.15076    0.1142 O1
TIDALPARAM=  0.958086  0.974188   1.15459    0.2781 M1
TIDALPARAM=  0.989049  0.998028   1.15116    0.1457 P1
TIDALPARAM=  0.999853  1.000147   1.21046    7.7281 S1
TIDALPARAM=  1.001825  1.003651   1.13775    0.2080 K1
TIDALPARAM=  1.005329  1.005623   1.24997    0.3936 PSI1
TIDALPARAM=  1.007595  1.013689   1.16771   -0.0469 PHI1
TIDALPARAM=  1.028550  1.044800   1.15719    0.1102 J1
TIDALPARAM=  1.064841  1.216397   1.15840    0.1663 OO1
TIDALPARAM=  1.719381  1.872142   1.16356    2.1925 2N2
TIDALPARAM=  1.888387  1.906462   1.17880    1.9890 N2
TIDALPARAM=  1.923766  1.942753   1.18698    1.4148 M2
TIDALPARAM=  1.958233  1.976926   1.17998    0.6928 L2
TIDALPARAM=  1.991787  2.002885   1.18552    0.2852 S2
TIDALPARAM=  2.004710  2.182843   1.18578    0.4622 K2
TIDALPARAM=  2.753244  3.081254   1.07216    0.3302 M3
```