Report of the CCM Working Group on Gravimetry

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19th CCM meeting, 25-26 May 2023

CONSULTATIVE COMMITTEE
FOR MASS AND RELATED QUANTITIES

WG Meetings held since last CCM

16-17 May, 2023, hosted by BEV Austria as Extended CCM-WGG meeting
18 Participants (10 CCM-WGG members, 8 invited/observers)

WG Meetings held since last CCM

"**Extended**" meeting by representatives from **International Association of Geodesy (IAG)**

Main topics:

1、Upcoming **CCM KC** on gravity acceleration (CCM.G-K2.2023, NIST pilot lab)

2、**Planning** of RMO KC and Additional Comparisons on gravity acceleration

3、Update of the document "**CCM-IAG Strategy** for Metrology in Absolute Gravimetry"

4、**Developments** of absolute gravimeters (with macroscopic and atomic sensors)

5、**Cooperation** with IAG on the International Terrestrial Gravity Reference System

6、**Knowledge** transfer through Guidance documents, scientific papers and research projects

Main actions taken and main achievements

Up to Now, 9 CMCs on gravity acceleration…

NO.	Country	Measurement method	Uncertainty (*k*=2)	Approved date
1	Austria	Free-fall experiment	10 µGal	2001-10-21
2	Finland	Free-fall experiment	8 µGal	2007-01-03
3	Italy	Free-fall experiment	15 µGal	2007-01-03
4	Switzerland	Free-fall experiment	8 µGal	2008-07-02
5	Ukraine	Free-fall experiment	20 µGal	2017-06-21
6	Mexico	Free-fall experiment	4.8 µGal	2020-04-01
7	Czech Rep.	Free-fall experiment	4.4 µGal	2020-09-15
8	Czech Rep.	Comparison against a gravity value of a reference station	6.0 µGal	2020-09-15

Main actions taken and main achievements

Up to Now, 9 CMCs on gravity acceleration… New one from SASO-NMCC

NO.	Country	Measurement method	Uncertainty (k=2)	Approved date
1	Saudi Arabia	Free-fall experiment	4.8 µGal	2022-2-8

CMCs in progress- CMCs:

NIM, China: under evaluation for both methods (measurement and calibration), peer review was completed in 2021 within APMP

NIMT, Thailand: under evaluation (measurement)
peer review within APMP

Main actions taken and main achievements

Guidance document on the uncertainty of FG5/X gravimeters is under preparation:

- knowledge transfer on the influence parameters

Site-dependent uncertainty
Coriolis effect
Floor recoil effect
Barometric pressure effect (diff. pressure, atmospheric attraction and loading correction, admittance factor)
Earth tides correction
Ocean loading correction
Polar motion correction

Instrumental uncertainty
Drag effect (residual gas)
Outgassing effect
Non-uniform magnetic field effect
Temperature gradient effect
Effect for electrostatics
Mass distribution effect (attraction of apparatus)
Laser beam verticality correction (glass wedges)
Trajectory verticality
Air gap modulation effect
Laser accuracy effect (distance measurement)
"Beat-mode" (inter-mode laser leak effects)
Index of refraction effect
Beam divergence correction (laser beam diameter, diffraction corr.)
Beam share effect
Clock effect (frequency standard)
Fringes timing effect (electronic phase shift, time interval asymmetry)
Finite value of speed of light effect
Retroreflector balancing (trihedron or test mass rotation)
Radiation pressure effect
Vertical gravity gradient
Data processing (start fringe and number of processed fringes)
Set up
Reference height (height measurement from a benchmark, effective height determination)
Air pressure measurement (air pressure correction - pressure sensor)
Seismic shocks
Reproducibility

Progressing the state of the art

Absolute gravimeters with cold-atom sensors: 1) Best instruments have uncertainty of about 2 µGal (2E-8 m/s^2). 2) AQG commercial atomic gravimeter took part at two Additional Comparisons showing repeatability of 3 µGal and the uncertainty of 8 µGal .

Absolute gravimeters with macroscopic sensors: still FG5/FG5X gravimeters are the most accurate: A set of newly determined corrections (signal distortion and dispersion, Coriolis, verticality) might be associated with measurements, which improve the uncertainty slightly below 2 µGal.

Gravity gradiometer (can simultaneous measurement of *g* and its vertical gradient) was developed in LNE France.

Liaison & stakeholders

Supporting NMIs CMCs and for the new realization of the kilogram （Kibble Balance）

Cooperation with IMEKO TC3 (Measurement of Force, Mass,Torque and Gravity), Gravity measurement was included in IMEKO TC3 last year.

New subcommittee on Gravimetry under EURAMET TC-M.

Liaison & stakeholders

Continuous cooperation with International Association of Geodesy (IAG).

- IAG SC 2.1: Land, Marine and Airborne Gravimetry
- IAG JWG 2.1.1: Establishment of International Gravity Reference System and Frame
- IAG WG Q.1: Quantum gravimetry in space and on ground

Ensure traceability to the International System of Units (SI) for gravimetry.

KCs completed and underway

Next CCM-KC (CCM.G-K2.2023) will be piloted by NIST in this September

- 16 instruments from NMIs or DIs plan to participate in the KC, which will be the largest number of KC instruments in the history of comparisons
- 2 atomic gravimeters from (LNE France and NIM China) plan to participate under the Additional Comparison (not defining KCRV)

KCs planed

CCM.G-K2.2023 will be held by NIST in this year. Technical Protocol of this KC has been discussed in the last CCM-WGG meeting.

Organization of RMO-KC in 2024/2025: EURAMET in Wettzell (BKG, Germany) – pilot lab is under discussion; APMP in NIM China or in KRISS South Korea is under discussion

Next CCM KC should be held in 2029

Program of work for the next 2 years

- Guidance on the evaluation of uncertainty of absolute gravimeters.
- Guidance on the evaluation of comparisons of absolute gravimeters.
- Knowledge transfer on measurement techniques and experiments.
- Support the International Terrestrial Gravity Reference System by establishing Comparison and reference stations for calibrations and validations of absolute gravimeters.
- Improvement of CMCs (increase number of CMCs and improve the uncertainty)

WG Meetings planned

Next CCM-WGG meeting plan to be held in 2024. Topics:

1、Discussion of the Draft A report of CCM.G-K2.2023

2、 Discussion on the update of “CCM-IAG Strategy for Metrology in Absolute Gravimetry”

Proposed changes (membership, chairmanship, ToRs)

No change proposals of CCM-WGG chairmanship and ToRs

Chair: Dr Shuqing WU, NIM,China
Vice-chair: Dr Vojtech Palinkas, VÚGTK – Czech

CCM-WGG has two kinds of membership (institutional and personal experts)

No change proposal on institute/organization membership

personal experts change proposal:

Dr. Michel Van Camp (Belgium) and Prof.Jan Krynski (Poland), left

Dr. Przemylaw Dykowski (Poland), new member

Thank you for your attention.

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