Report of the CCM Working Group on Gravimetry (CCM-WGG)

Alessandro Germak (INRiM)

17th CCM meeting, 16 May 2019

Bureau International des Poids et Mesures

Proposed changes to membership

- No new member proposal

Actual members (22):

14 NMIs

3 DIs

4 personal

1 International

- **BEV** (Bundesamt für Eich- und Vermessungswesen)
- **BGI** (Bureau Gravimetrique International)
- **BIPM** (Bureau International des Poids et Mesures)
- **FGI** (Finnish Geospatial Research Institute)
- **INRIM** (Istituto Nazionale di Ricerca Metrologica)
- **KRISS** (Korea Research Institute of Standards and Science)
- **LGUL** (Faculté des Sciences, de la Technologie et de la Communication)
- **LNE-SYRTE** (Observatoire de Paris/Systèmes de Référence Temps-Espace)
- **METAS** (Federal Institute of Metrology METAS)
- **NIM** (National Institute of Metrology)
- **NIST** (National Institute of Standards and Technology, United States Department of Commerce)
- **NMIJ/AIST** (National Metrology Institute of Japan, AIST)
- **NPL** (National Physical Laboratory)
- **NRC** (National Research Council of Canada)
- **SASO-NMCC** (Saudi Organization for Standardization, Metrology and Quality)
- **UME** (National Metrology Institute of Turkey)
- **VNIIM** (D.I. Mendeleyev Institute for Metrology)
- **VUGTK** (Research Institute of Geodesy, Topography and Cartography)
- Dr Reinhard **Falk**
- Prof. James **Faller**
- Prof. Dr Jan **Krynski**
- Dr Michel **Van Camp**
- **RMO** Technical Committee chairs in the field of Mass and Related Quantities or their representatives

Proposed changes to membership

- Proposed change in chairmanship:
  - ***Chair**:* *Dr. WU Shuqing (NIM, China)*
  - ***Vice chair**: Dr. Vojtech Pálinkás (VUGTK, Czech Republic)*

WG Meetings held since last CCM

- 13th may, 2019

  BIPM

  Sèvres, France

21 Participants (16 members, 5 invited/observers)

WG Meetings planned

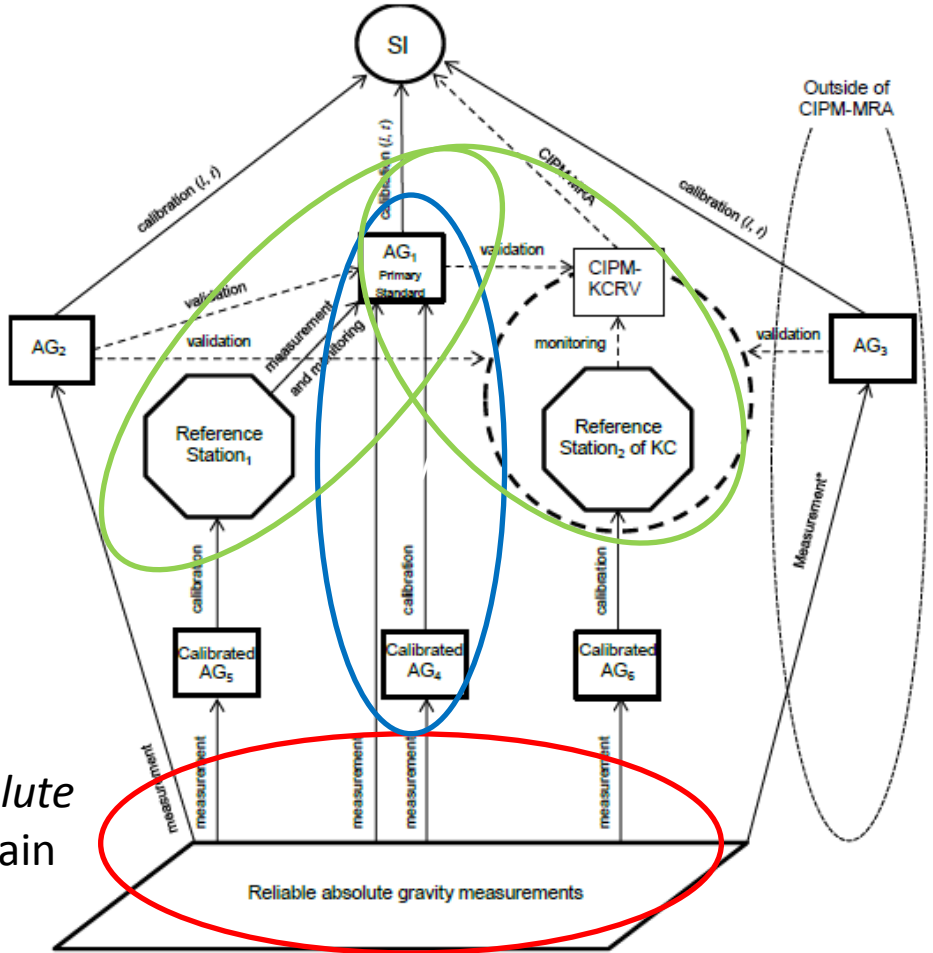
- Next WGG meeting on 2021 in coincidence of IAG general assembly and meetings in Vienna (hosted by BEV)

Main actions taken and main achievements

- Organization and promotion of:
  - Key Comparisons (CCM and regionals)
  - CMCs submissions
  - Metrological issues
  - Liasons with geodetic/geophisicist community:

Main actions taken and main achievements

- Different CMCs:
  - Absolute measurement (on stable site)
  - Calibration of AG:
    - By direct comparison with other AG
    - By comparison with a reference station



"CCM – IAG Strategy for Metrology in Absolute Gravimetry": Scheme of the traceability chain

Main actions taken and main achievements

- New CMCs:
  - **NSC Ukraina**, (June 2017)
- In progress:
  - **VÚGTK, Czech Republic:** submitted for both absolute measurements and *calibration of absolute gravimeter* (first CMC submitted in this field): approved by EURAMET on Feb. 2019 and now under evaluation from the other RMOs
  - **CENAM, Mexico:** finished the preparation process (peer rewiew and participation to a KC) for the CMC presentation and now they are under submission
  - **NIM, China**: under evaluation for both (measurement and calibration)
  - **NIMT, Thailand**: under evaluation (peer review on Feb.2020)

Progressing the state of the art

- Better understanding on uncertainty in measurement (possible systematic errors on comparisons of FG5 type dominant AGs). *Agreed expanded uncertanty (95% confidence level) of FG5 type AGs: about* ***4.5x10-8*** *m/s²*
- Giving better possibilities in traceability for measurements (implementing all possible traceability paths described in the document «*CCM – IAG Strategy for Metrology in Absolute Gravimetry")*
- Supporting emerging technolgies of AGs (quantum…)

Progressing the state of the art

- 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
Others

Liaison & stakeholders

- NMIs: for supporting their CMCs and for the new realization of the kilogram
- Liasons with geodetic/geophisicist community:
  - IAG SC2.1 Gravimetry and Gravity Networks:
    - SG 2.1.1: Techniques and metrology in terrestrial (land, marine, airborne) gravimetry
    - JWG 2.1.1: Establishment of a global absolute gravity reference system
    - JWG 2.1.2: Unified file formats and processing software for high-precision gravimetry

KCs completed and underway

- Key Comparisons:
  - **CCM.G-K2.2017,** *Pilot Lab:* NIM, China, Oct. to Nov. 2017, **Draft B**
  - **EURAMET.M.G-K3,** *Pilot Lab:* VÚGTK – Czech Rep., Apr. to June 2018, **Draft A**
  - **SIM.M.G-K1**, Pilot lab: NIST-USA, Oct. 2016, **Approved for equivalence, Results available**
  - **COOMET.M.G-S1,** Pilot lab: NSC, Ukraine, Jan. 2016, **Approved and published**

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Site: Changping Campus of NIM, China

Pilot Lab: NIM, China

Date: Oct. to Nov. 2017

30 absolute gravimeters (AGs):

13 KC and 17 PS instruments

(4+2 quantum/atomic gravimeters)

Draft B circulated

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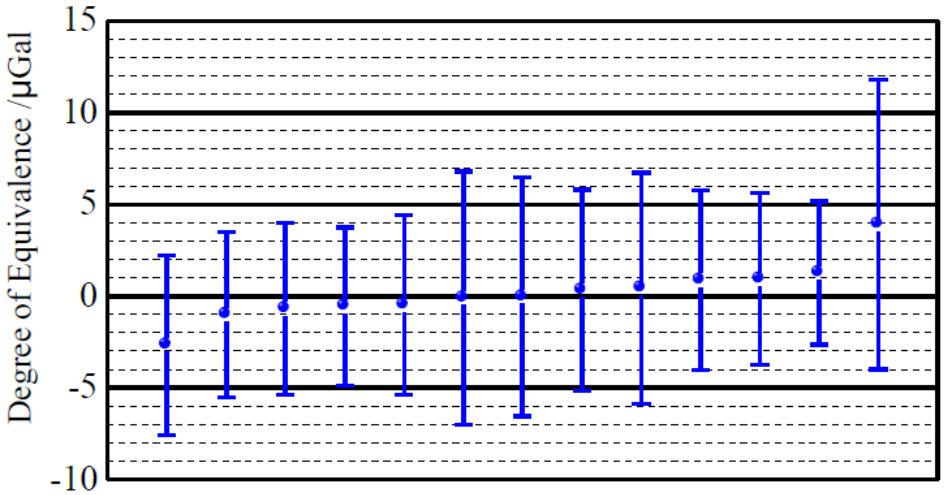

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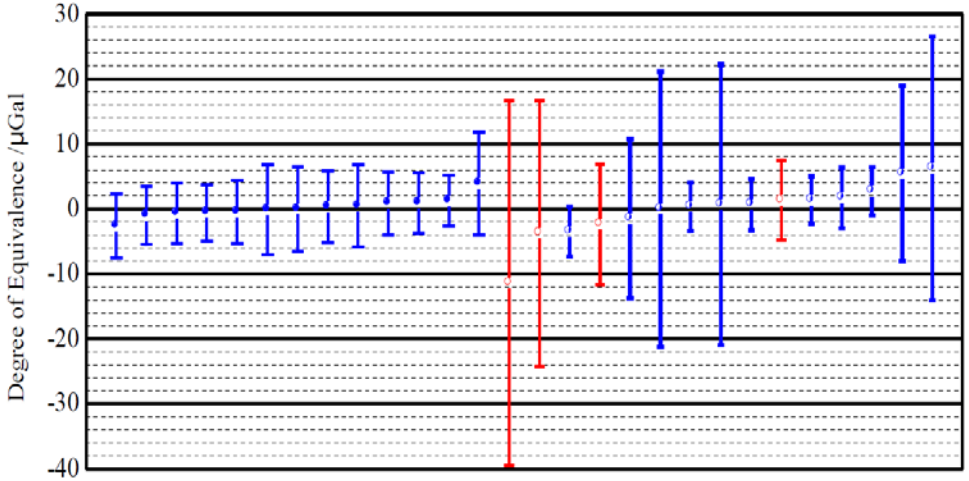

KCs completed and underway

- Key Comparisons:

EURAMET.M.G-K3

Site: Geodetic Observatory Wettzell (GOW), BKG

Bad Kötzting, Germany

Pilot Lab: VÚGTK – Czech Rep.

Date: Apr. to June 2018

16 absolute gravimeters (AGs):

5 KC and 11 PS instruments

Draft A circulated

KCs completed and underway

- Key Comparisons:

SIM.M.G-K1

Site: Table Mountain Geophysical Observatory (TMGO)

Boulder, Colorado

Pilot lab: NIST-Gaithersburg

Date: Oct. 2016

12 absolute gravimeters (AGs):

4 KC and 8 PS instruments

Approved for equivalence, Results available (2017)

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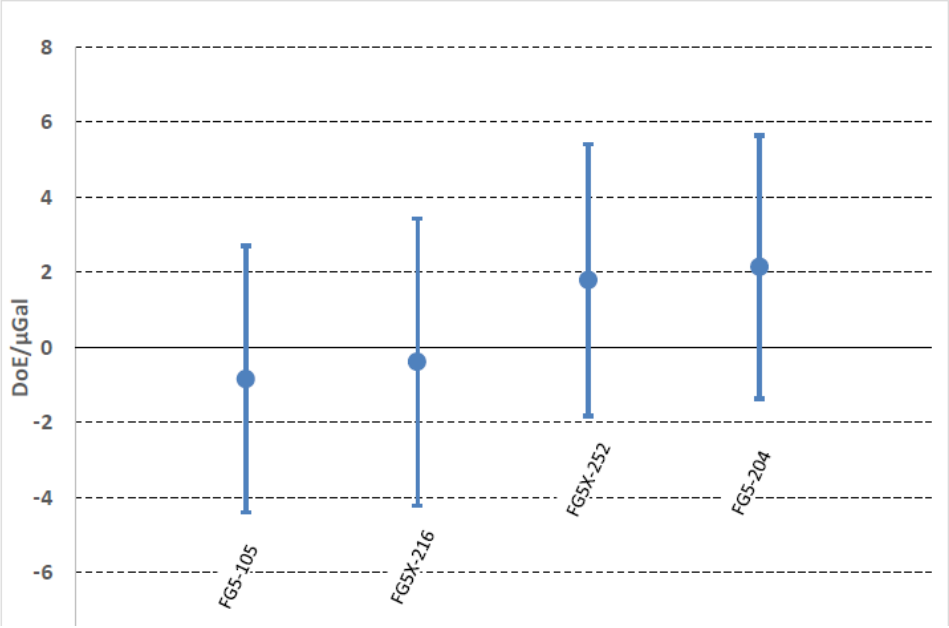

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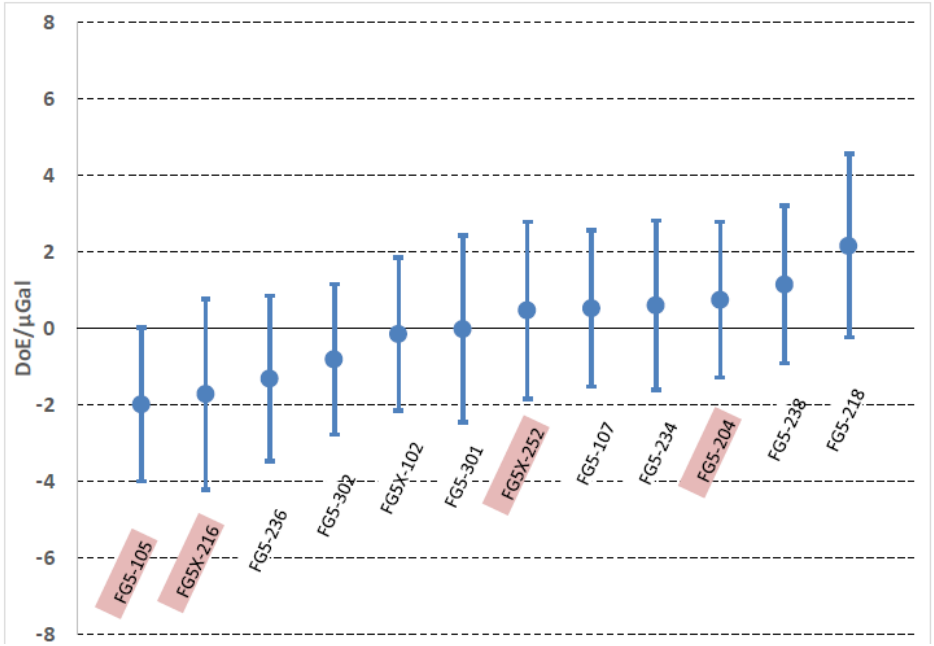

KCs completed and underway

- Key Comparisons:

COOMET.M.G-S1

Site: INRiM, Torino, Italy

Pilot lab: NSC, Ukraine

Date: Jan. 2016

2 absolute gravimeters (AGs):

Approved and published (2017)

Agreement between the two participants

KCs planed

- Next CCM-KC in 2023
- Possible next RMO KC immediately after the CCM-KC

Program of work for the next 5 years

- Definition of the features of **reference sites**, improving the quality and the numbers in any Region
- Organization of technical **Seminar/Workshop** (in coincidence of WGG meetings)
- Improvement of **CMCs**
- Organization of **Key Comparisons** with periodicity of six years (next on 2023)
- Support the Global Absolute Gravity Reference System and the International Gravity Reference Frame - **IGRF** (Resolution No. 2 of the IAG at the XXVI General Assembly of the IUGG in 2015). The achieved uncertainty for measurement at reference stations should be better than 10 µGal, including systematic effects.

Thank you for your attention

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