CCM-Working Group on Gravimetry (CCM-WGG)

Alessandro Germak

INRIM, Torino, Italy

Terms of Reference

- To propose key comparisons to the CCM;
- To maintain contact with international organizations and stakeholders active in gravimetry;
- To support stakeholders to ensure and promote the traceability of gravimetry to the SI;
- To follow the main research activities in gravimetry.

next 5 years program of work

- to organize of KCs /Pilot Studies;
- to support the traceability in gravimetry;
- to promote scientific exchanges on matters relating gravimetry (i.e. workshops, meetings, conferences, etc.);
- to improve CMC declarations on gravimetry:
  - it is expected to have two more CMC declarations from NMIs or Dis in 2015.
  - the CMC will be reviewed in order to cover both the measurements and calibration activities.

Present WGG Membership

1.	Dr Henri Baumann	(METAS)	Switzerland
2.	Dr Mirjam Bilker-Koivula[1]	(FGI)	Finland
3.	Dr Sylvain Bonvalot	(BGI)	France
4.	Dr In-Mook Choi	(KRISS)	Republic of Korea
5.	Prof. James Faller	(NIST)	USA
6.	Prof. Olivier Francis		Luxemburg
7.	Dr Alessandro Germak	(INRIM)	Italy
8.	Dr Baki Karaboce	(UME)	Turkey
9.	Prof. Dr Jan Krynski		Poland
10.	Dr Jacques Liard	(NRC)	Canada
11.	Dr Shigeki Mizushima	(NMIJ/AIST)	Japan
12.	Dr Vojtech Palinkas	(VUGTK)	Czech Republic
13.	Dr Franck Pereira	(SYRTE)	France
14.	Dr Lennart Robertsson		(BIPM)
15.	Dr Ian A. Robinson	(NPL)	United Kingdom
16.	Dr Diethard Ruess	(BEV)	Austria
17.	Dr Michel Van Camp		Belgium
18.	Dr Leonid Vitushkin[2]	(VNIIM)	Russian Federation
19.	Dr Herbert Wilmes		Germany
20.	Dr Shuqing Wu	(NIM)	China

Proposed Changes to Membership

- **Dr Leonid Vitushkin**, (VNIIM), Russian Federation (past chairman, substitution of Dr. Evgeny Krivtsov)

- **Dr Mirjam Bilker-Koivula**, (FGI), Finland (substitution of Dr. Jaakko Mäkinen)

WGG Meetings held since last CCM

- 8th meeting — 23 February 2015 - BIPM

WGG Meetings planned

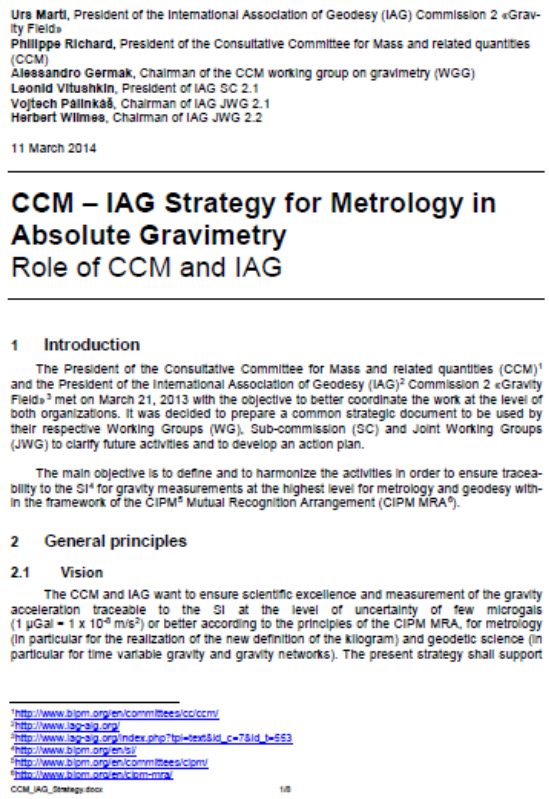
Next meeting in 2016, 23-25 of February in Bruxelles, at Royal Observatory of Belgium,

in conjunction with a Workshop on Absolute Gravimetry jointly organized with IAG SC2.1 and JWGs 2.1 and 2.2.

Major WGG issues handled by correspondence

CCM - IAG Strategy for Metrology in Absolute Gravimetry: Role of CCM and IAG.

- The main objective is to define and to harmonize the activities in order to ensure traceability to the SI for gravity measurements at the highest level for metrology and geodesy within the framework of the CIPM Mutual Recognition Arrangement (CIPM MRA).



Urs Marti, President of the International Association of Geodesy (IAG) Commission 2 «Gravity Field»
Philippe Richard, President of the Consultative Committee for Mass and related quantities (CCM)
Alessandro Germak, Chairman of the CCM working group on gravimetry (WGG)
Leonid Vitushkin, President of IAG SC 2.1
Vojtech Pálinkáš, Chairman of IAG JWG 2.1
Herbert Wilmes, Chairman of IAG JWG 2.2

11 March 2014

CCM – IAG Strategy for Metrology in Absolute Gravimetry
Role of CCM and IAG

1 Introduction

The President of the Consultative Committee for Mass and related quantities (CCM)[1] and the President of the International Association of Geodesy (IAG)[2] Commission 2 «Gravity Field»[3] met on March 21, 2013 with the objective to better coordinate the work at the level of both organizations. It was decided to prepare a common strategic document to be used by their respective Working Groups (WG), Sub-commission (SC) and Joint Working Groups (JWG) to clarify future activities and to develop an action plan.

The main objective is to define and to harmonize the activities in order to ensure traceability to the SI[4] for gravity measurements at the highest level for metrology and geodesy within the framework of the CIPM[5] Mutual Recognition Arrangement (CIPM MRA[6]).

2 General principles

2.1 Vision

The CCM and IAG want to ensure scientific excellence and measurement of the gravity acceleration traceable to the SI at the level of uncertainty of few microgals (1 μGal = 1 x 10^{-8} m/s^2) or better according to the principles of the CIPM MRA, for metrology (in particular for the realization of the new definition of the kilogram) and geodetic science (in particular for time variable gravity and gravity networks). The present strategy shall support

[1] http://www.bipm.org/en/committees/cc/ccm/
[2] http://www.iag-aig.org/
[3] http://www.iag-aig.org/index.php?tpl=text&id_c=7&id_t=553
[4] http://www.bipm.org/en/si/
[5] http://www.bipm.org/en/committees/cipm/
[6] http://www.bipm.org/en/cipm-mra/

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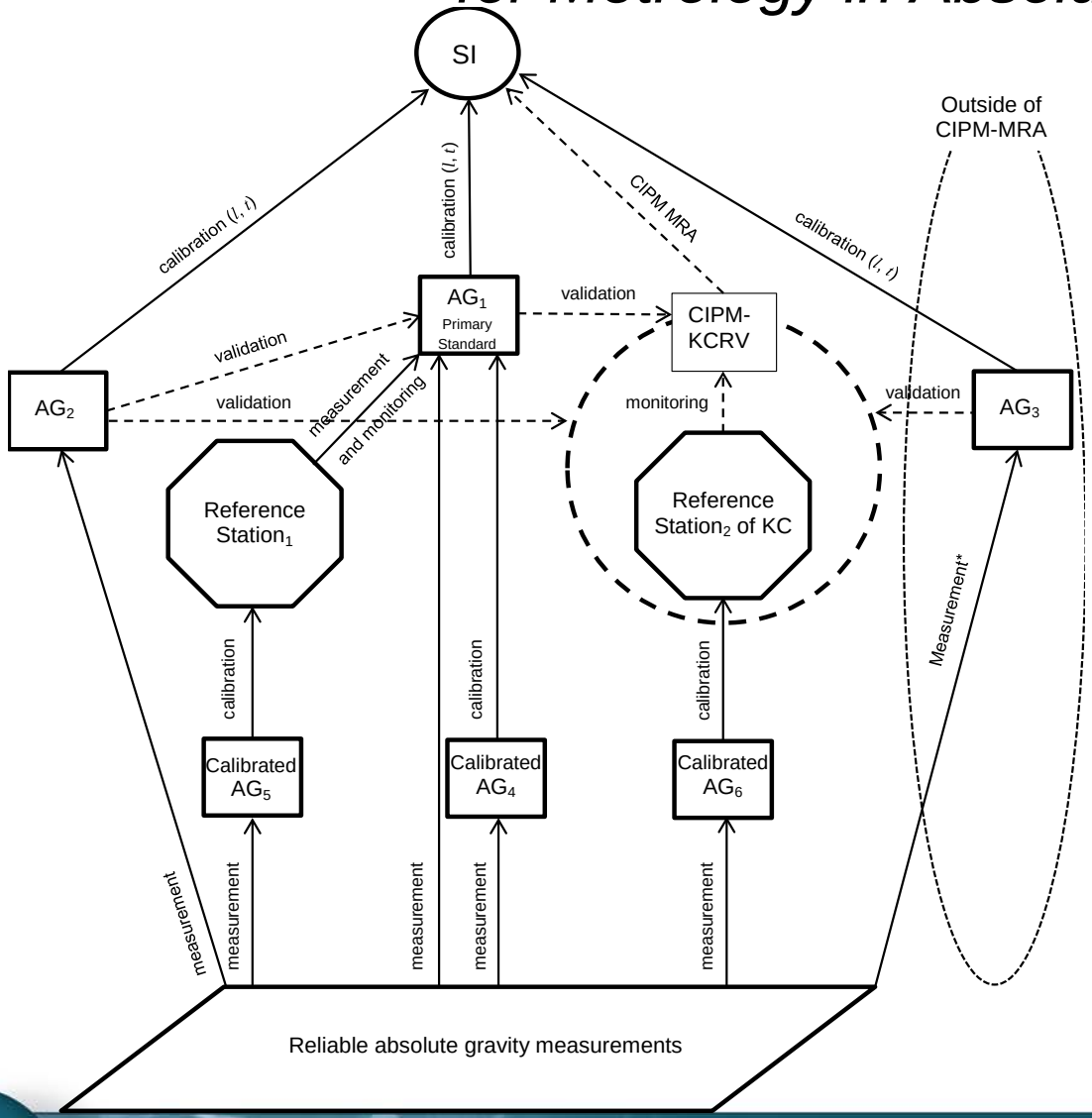
Available on WGG Website (open access)

Scheme of the traceability chain in gravimetry, according to CCM IAG Strategy for Metrology in Absolute Gravimetry



AG1: Absolute Gravimeter (Primary Standard) with independent traceability to SI units (through calibration of laser and clock) validated with the KCRV of a KC. AG2: Absolute Gravimeter with independent traceability to SI units validated in comparison with a Primary Standard Absolute Gravimeter or with the CIPM-KCRV.
AG3: Absolute Gravimeter with independent traceability to SI units validated with KCRV of an additional comparison outside the scope of CIPM MRA.
AG4: Absolute Gravimeter calibrated against a reference gravimeter (AG1).
AG5: Absolute Gravimeter calibrated against a gravity value of the Reference Station1 (measured by AG1 and carefully monitored).
AG6: Absolute Gravimeter calibrated against a gravity value of a Reference Station2 (measured dur-ing a KC and carefully monitored.

Measurement* In this case, measurements carried out by AG3 cannot establish any measurement certificate for ensuring the traceability to the SI.

Liaisons with RMO KCs

RMO and Name	Quantity	Year	Type	Status
APMP.M.G-S1	Free-fall acceleration	2012	Supplementary comparison	Report in progress, Draft A
EURAMET.M.G-K1	Free-fall acceleration	2011	Key comparison	Approved for equivalence, Results available
EURAMET.M.G-S1	Free-fall acceleration	2008	Supplementary comparison	Approved and published

KCs / Pilot Studies underway

Name	Quantity	Year	Type	Status
CCM.G-K2[1]	Free-fall acceleration	2013	Key comparison	Report in progress, Draft B[2]

[1]CCM.G-K2+Pilot study

[2]*Final Draft available*

Carried out at: Underground Laboratory for Geodynamics in Walferdange, Luxembourg

Pilot: METAS

CCM.G-K2

#	Country or Province	Institution	NMI or DI	Gravimeter	Operator(s)
1	Austria	Federal Office of Metrology and Surveying and Surveying (BEV)	YES	FG5-242	Christian Ullrich
2	Belgium	Royal Observatory of Belgium	NO	FG5-202	Michel van Camp, Stefaan Castelein
3	Brazil	Observatório Nacional	NO	FG5-223	Mauro Andrade de Sousa, Rodrigo Lima Melhorato
4	China	National Institute of Metrology	YES	NIM-3A	Shuqing Wu, Chunjian Li, Jinyi Xu, Duowu Su
5	China	Tsinghua University	NO	T-2	Hua Hu, Kang Wu, Gang Li, Zhe Li
6	Chinese Taipei	Industrial Technology Research Institute	YES	FG5-231	Wen-Chi Hsieh
7	Czech Republic	Geodetic Observatory Pecný	YES	FG5-215	Vojtech Pálinkás Jakub Kostelecký
8	Finland	Finnish Geodetic Institute	YES	FG5X-221	Jaakko Mäkinen, Jyri Näränen
9	France	LNE-SYRTE	YES	CAG-01	Sébastien Merlet, Franck Pereira Dos Santos, Pierre Gillot
10	France	Institut de Physique du Globe de Strasbourg	NO	FG5-206	Jacques Hinderer, Jean-Daniel Bernard
11	France	Géosciences Montpellier – CNRS -Université de Montpellier 2	NO	FG5-228	Nicolas Le Moigne,
12	Germany	Leibniz Universität Hannover	NO	FG5X-220	Olga Gitlein, Manuel Schilling
13	Germany	Federal Agency for Cartography and Geodesy	NO	FG5-301	Reinhard Falk, Herbert Wilmes
14	Italy	INRIM-Istituto Nazionale di Ricerca Metrologica	YES	IMGC-02	Alessandro Germak, Emanuele Biolcati, Claudio Origlia
15	Italy	ASI (agenzia Spaziale Italiana)	NO	FG5-218	Francesco Schiavone, Domenico Iacovone
16	Japan	National Metrology Institute of Japan	YES	FG5-213	Shigeki Mizushima
17	Luxembourg	University of Luxembourg	NO	FG5X-216	Olivier Francis, Gilbert Klein, Marc Seil
18	Poland	Institute of Geodesy and Cartography	NO	A10-020	Marcin Sękowski, Przemysław Dykowski
19	Republic of Korea	Korea Research Institute of Standards and Science	YES	FG5X-104	In-Mook Choi, Min-Seok Kim
20	Spain	Instituto Geográfico Nacional	NO	A10-006	Ana Borreguero, Sergio Sainz-Maza, Maria
21	Sweden	Lantmäteriet – the Swedish mapping, cadastral and land registration authority	NO	FG5-233	Andreas Engfeldt, Jonas Agren
22	Switzerland	Federal Office of Metrology - Metas	YES	FG5X-209	Henri Baumann
23	The Netherlands	Delft University of Technology	NO	FG5-234	René Reudink
24	USA	National Geodetic Survey	NO	FG5-102	Marc Eckl
25	USA	Micro-g LaCoste Inc.	NO	FG5X-302	Derek van Westrum, Ryan Billson, Brian Ellis

CCM.G-K2

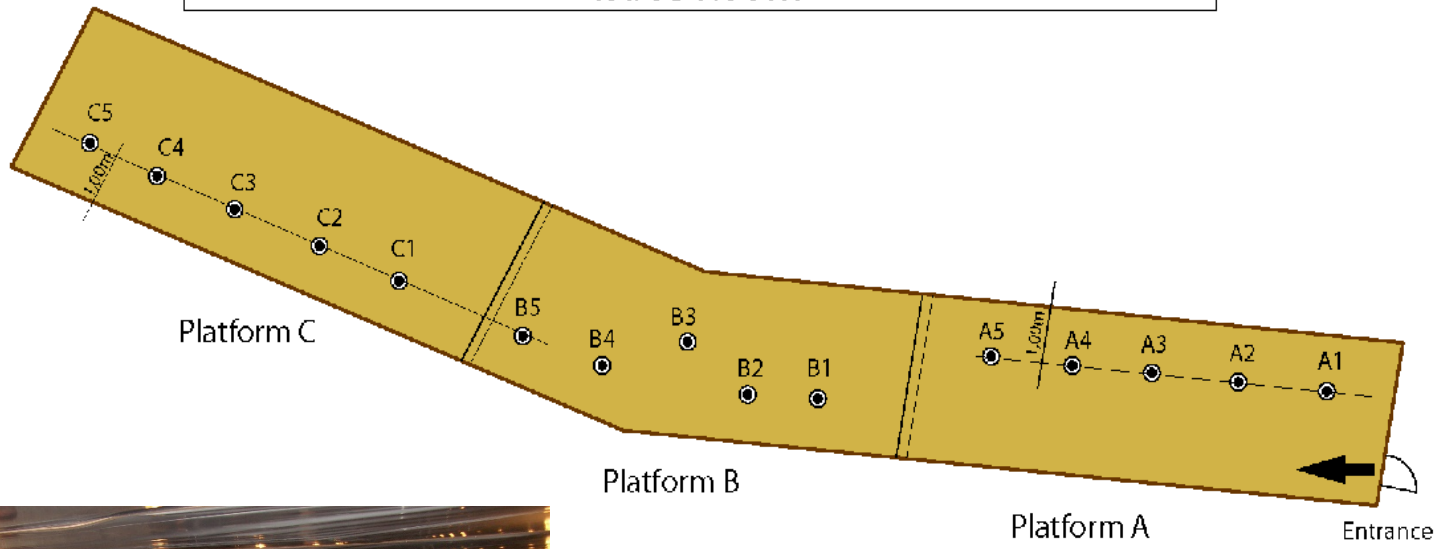
25 gravimeters (7 different types):

- 21 commercial: FG5 (2 types), FG5X, A-10
- 1 Atomic gravimeter
- 1 Rise-and-fall
- 2 new prototypes

65 operators

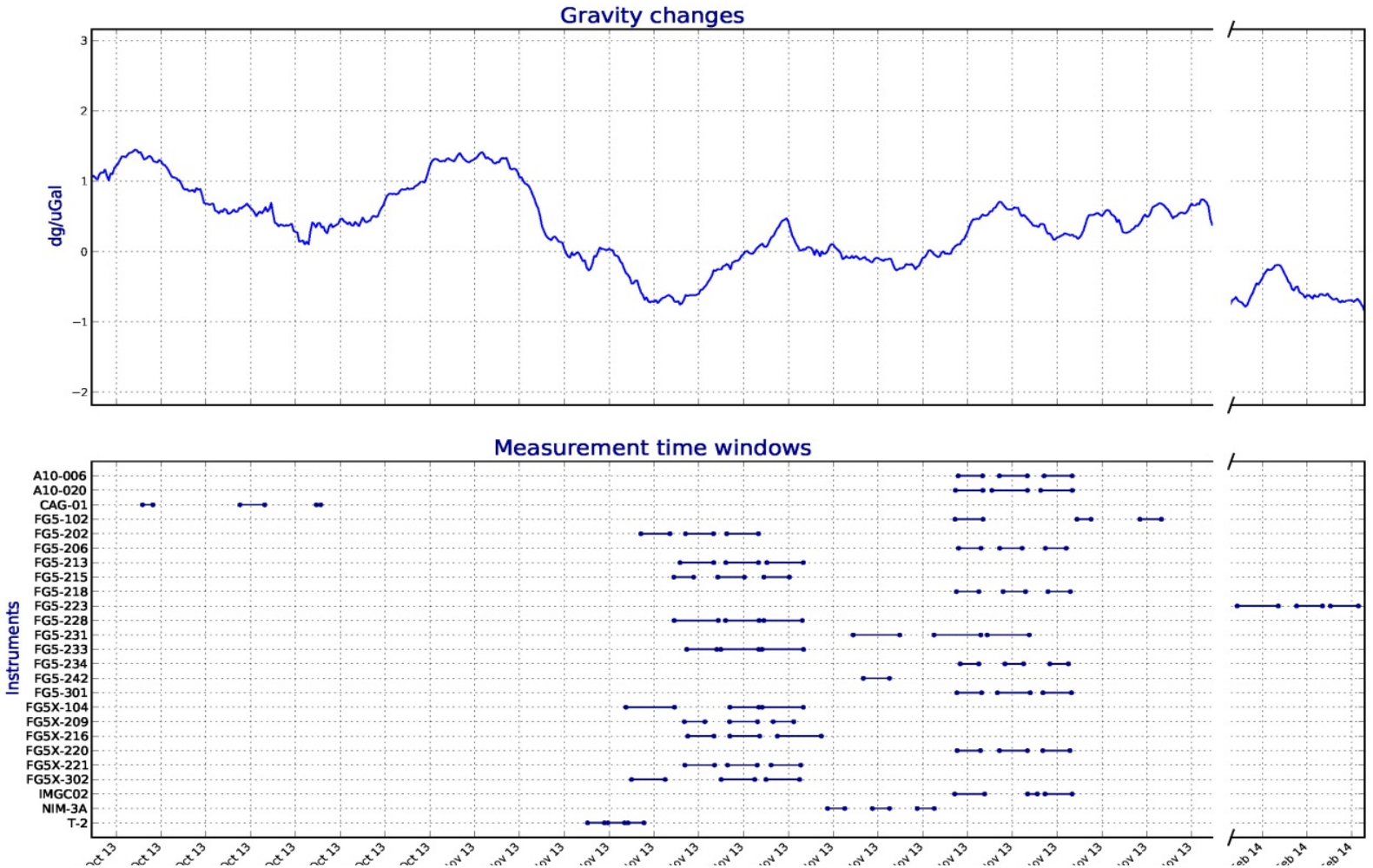
CCM.G-K2

Underground Laboratory of Geodynamics in Walferdange
ISIAG Room

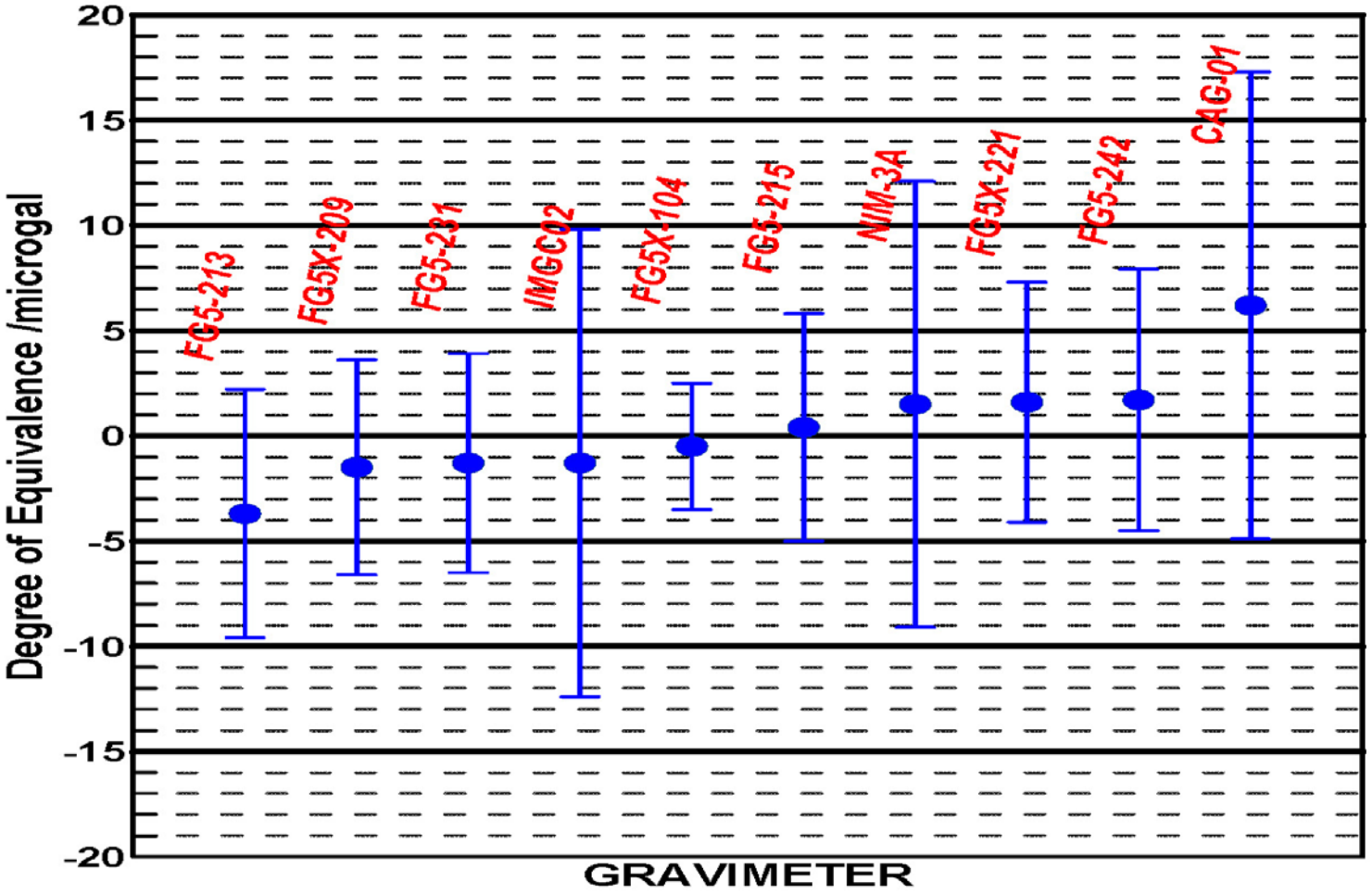


◉ Absolute Gravimeter

CCM.G-K2

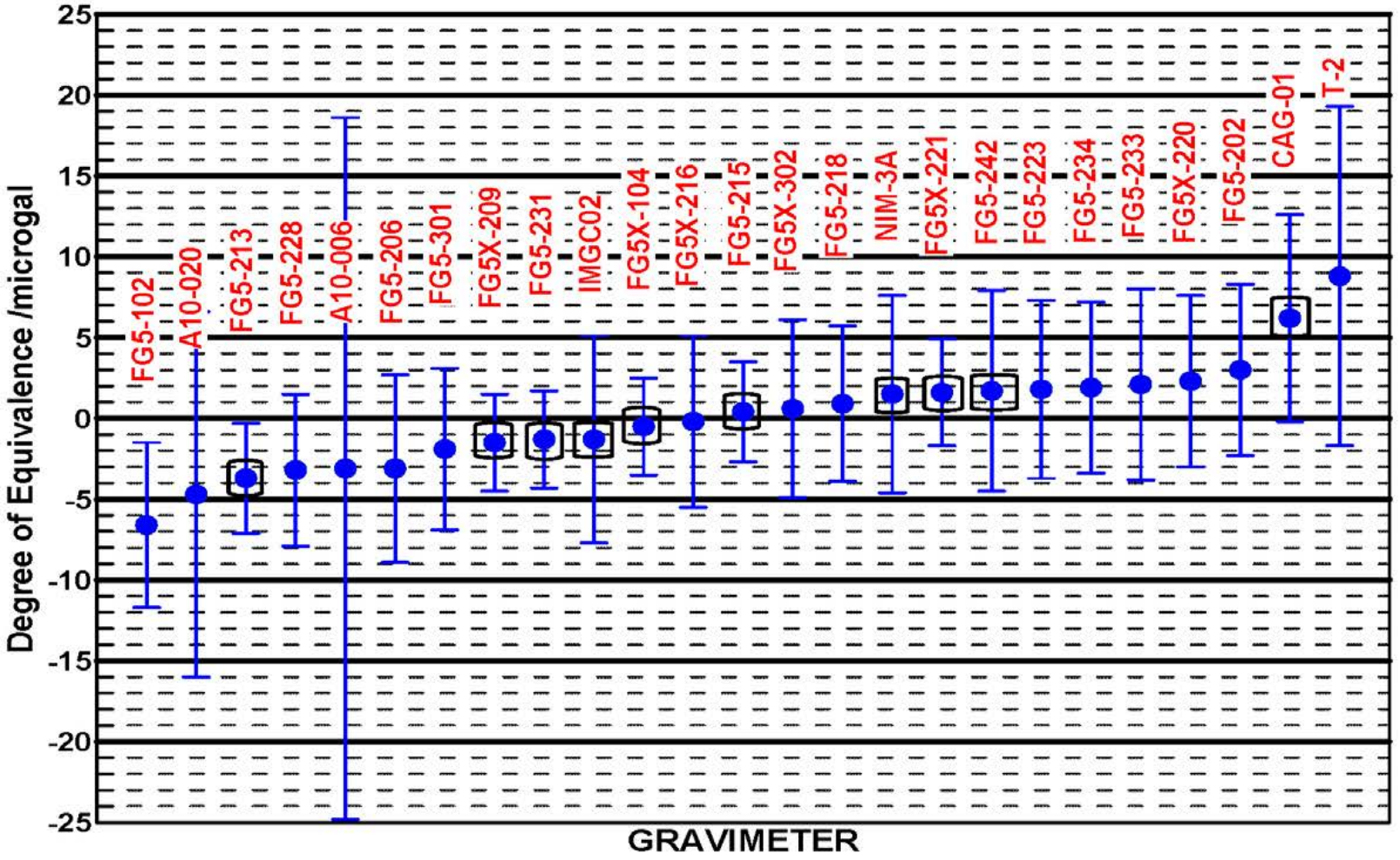

Gravity changes
dg/uGal
3
2
1
0
−1
−2
Measurement time windows
Instruments
A10-006
A10-020
CAG-01
FG5-102
FG5-202
FG5-206
FG5-213
FG5-215
FG5-218
FG5-223
FG5-228
FG5-231
FG5-233
FG5-234
FG5-242
FG5-301
FG5X-104
FG5X-209
FG5X-216
FG5X-220
FG5X-221
FG5X-302
IMGC02
NIM-3A
T-2
Oct 13
Nov 13
Feb 14

CCM.G-K2


Degree of Equivalence /microgal
20
15
10
5
0
-5
-10
-15
-20
FG5-213
FG5X-209
FG5-231
IMGC02
FG5X104
FG5-215
NIM-3A
FG5X-221
FG5-242
CAG-01
GRAVIMETER

CCM.G-K2

Pilot Study Results



KCs planned

APMP.G-K1, Free-fall acceleration

Date: 2015

Site: Changping Campus, Beijing, China

Pilot laboratory: NIM,China

EURAMET.G-K2, Free-fall acceleration

Date: 2015

Site: Underground Laboratory for Geodynamics in Walferdange, Luxembourg

Pilot Laboratory: VUGTK, Czech Republic

CCM.G-K3, Free-fall acceleration

Date: 2017

Site: Changping Campus, Beijing, China

Pilot laboratory: NIM, China

Are the current and planned KCs sufficient for CMCs in gravimetry?

- They are sufficient for supporting the present CMCs:

  According to CCM-IAG strategy document:

  - Year 1 — CIPM KC
  - Year 1 + *x* — RMO KCs
  - Year 1 + *y* — Next CIPM KC

The periodicity *x* is defined by the RMOs based on a recommendation of the RMO TC and the periodicity *y* is defined by the CCM on the recommendation of the CCM WGG.

Traceability to the SI according to the can be performed at any time according to the specific needs of the customers (for example for the validation of the instrument stability).

Are the current and planned KCs sufficient for CMCs in gravimetry?

- The CCM-WGG unanimously recommend a periodicity of 4 years for CIPM KCs.
- The CCM-WGG notes that in RMOs no TCs has been created. So also the periodicity for EURAMET comparisons has been decided at CCM-WGG level (4 years, with a shift of two years from CIPM KCs).

Highlight any major successes (since the last CCM)

Approval of CCM - IAG Strategy for Metrology in Absolute Gravimetry.

Highlight any major problems (since the last CCM)

- Many debates about the organization of the next Key Comparison;
- problems between the previous WGG chairman and the CCM President (new WGG chairman has been nominated).

Highlight technology trends and challenges in gravimetry

- Watt balance experiments need accurate g measurements.
- Worldwide interesting developments of new instruments based on very different technologies.
- New prototypes are under development and are emerging start-ups to make these prototypes accessible to the international scientific community.
- The number of researchers involved is getting bigger. Many of the common problems are studied in several laboratories by increasing the opportunity for discussion of these issues.
- Several of these laboratories are equipped, or are gearing up to better address these researches, including also the possibility of hosting international comparisons.
- Fundamental need for a periodic comparison of primary instruments.It is always very useful and important for the detection of possible systematic errors; in fact, only with increasing independent technologies that realize measurements with primary methods is possible to compare uncorrelated measurements.

Thank you for your attention!