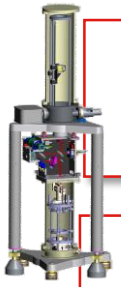
Towards the establishment of a global absolute gravity reference system

Meeting of IAG JWG 2.1.1 at EGU General Assembly 2018

Chair: Hartmut Wziontek, BKG (Germany)

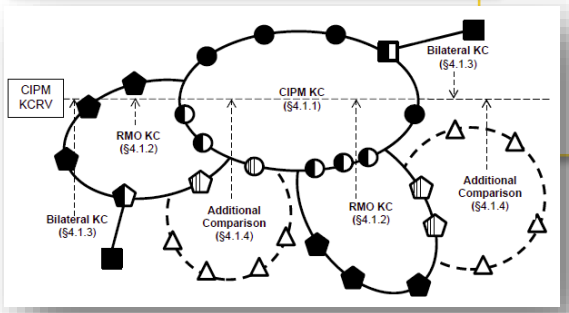
Vice-chair: Sylvain Bonvalot, BGI (France)

Proposed Concept for a Global Absolute Gravity Reference System

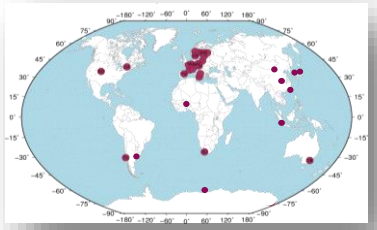


Absolute Gravimeters

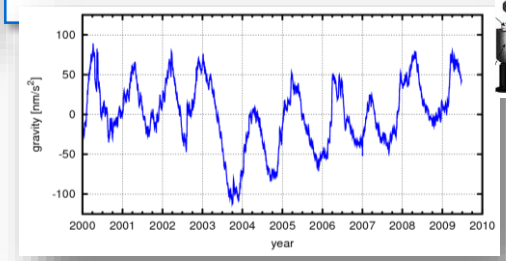
Intercomparisons:
CCM-KC, RMO-KC
Geodetic Comparisons
with linked CRF



Gravity reference stations
with continuous comparison reference function



Continuously operated most stable relative gravimeters (SG)



Definition of standard correction models
(Tides, Atmosphere, Polar Motion, Hydro)

- to establish a gravity reference frame by globally distributed reference stations linked to the international comparisons of absolute gravimeters where precise gravity reference is available at any time,

Two Aspects of the Realization (cont. 2017)

Long term stable **Reference Level**:
Absolute gravimeters
monitored at reference stations

Infrastructure:
Accessibility of the system
by a global set of stations,
compatible with the reference level

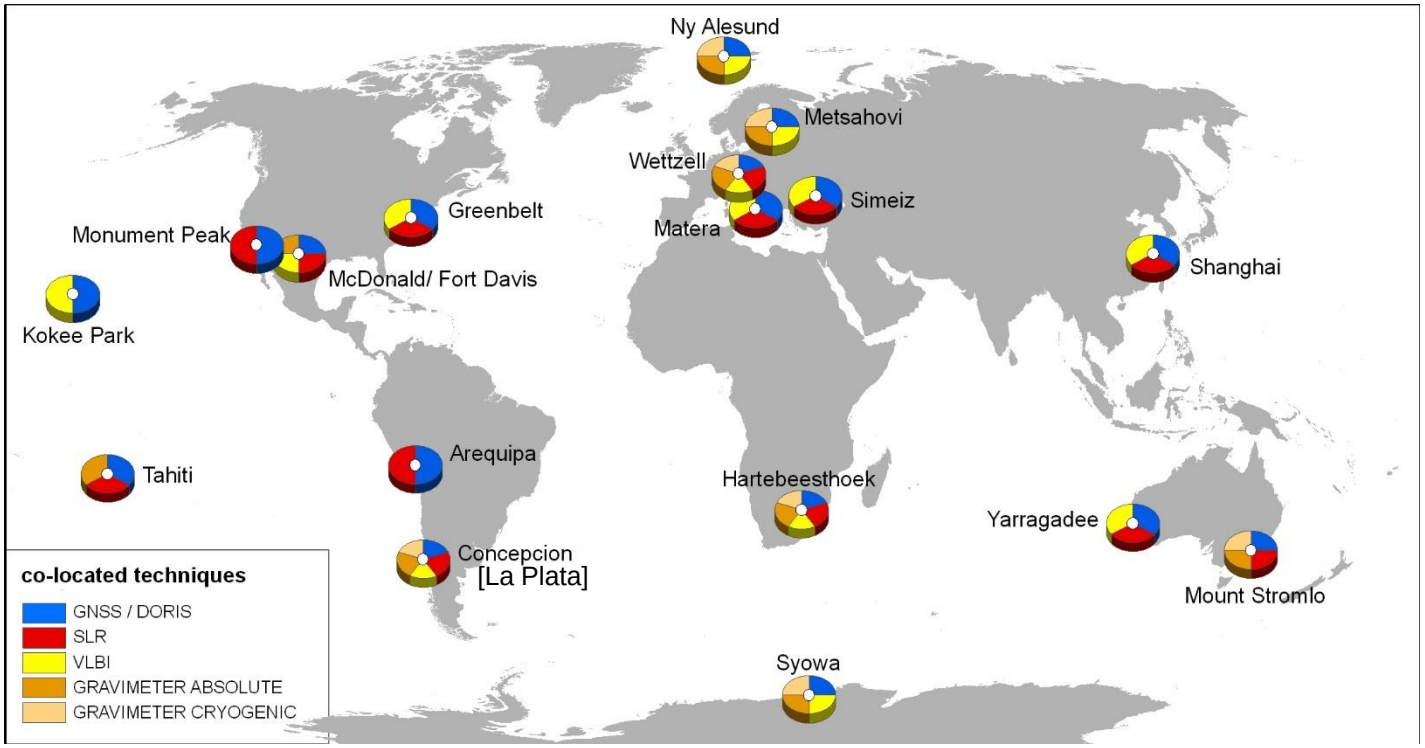
Repeated comparisons (monitoring of AG) at international/regional level

- **Reference stations:** continuous gravity reference function (Superconducting/ Quantum Gravimeters, repeated AG) preferred but no exclusive
- **Comparison sites**: reference station with extended facilities for comparisons
- **Core station**: Link to space geodetic techniques (GNSS, SLR; VLBI)
- Accuracy: A few µGal range

- Replacement of IGSN71, by a set of absolute gravity stations accessible for any users
  (including those not operating an AG!)
- Compatibility by Comparisons (Additional comparisons) for all AG, e.g. A10, at reference stations
  (at any time: SG / IGETS)
- The new infrastructure needs the support and collaboration with National agencies
- Documented in AGrav

Reference Sites: GGOS core stations

- Link to space geodetic techniques (GNSS, SLR, VLBI)
- Stations to be identified



Status 2010

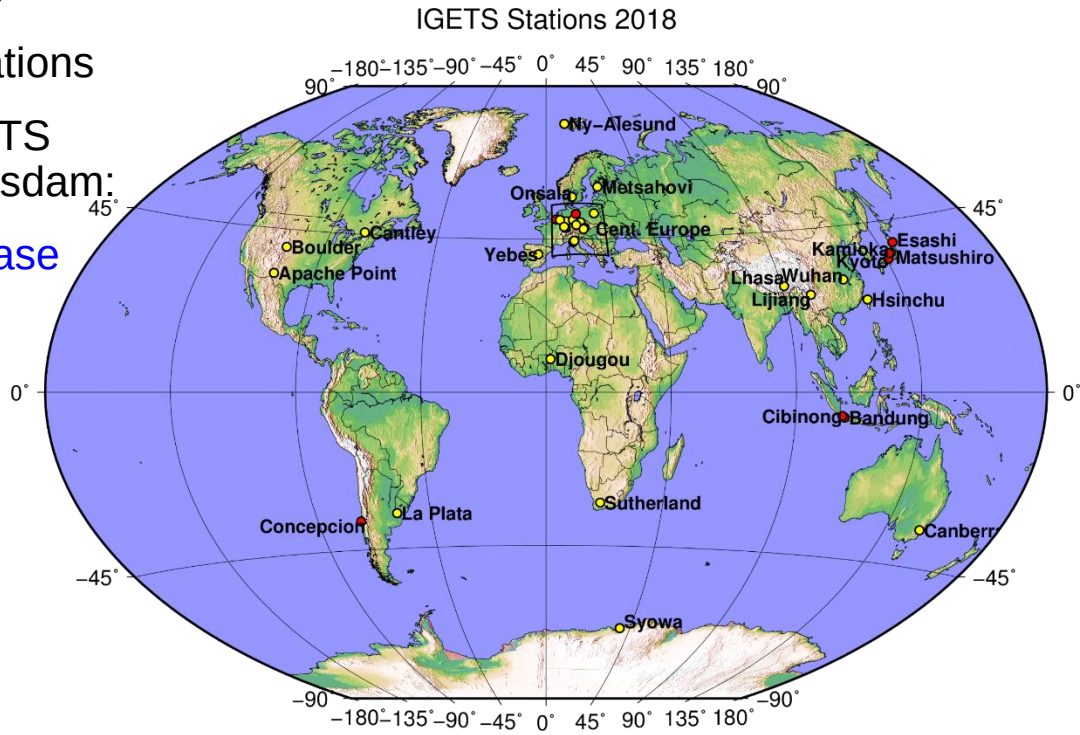
Reference Site Selection: IGETS

Continuous Gravity Monitoring with Superconducting Gravimeters:

- Potential Reference stations for AG
- Monitoring of temporal gravity variations
- 37 SG Stations included in the IGETS database, hosted at ISDC GFZ Potsdam:

http://isdc.gfz-potsdam.de/igets-data-base

International Geodynamics and Earth Tides Service (IGETS)



Reference Site Selection: IGETS

Selection from active 21 (+2) stations:

Europe (13+1): BG, BH, CO, MC, MB, ME, MO, NY, OS, PE, ST, WE, YS, [BF]

North America (3): AP, BO (reactivation), CA

South America (1): LP

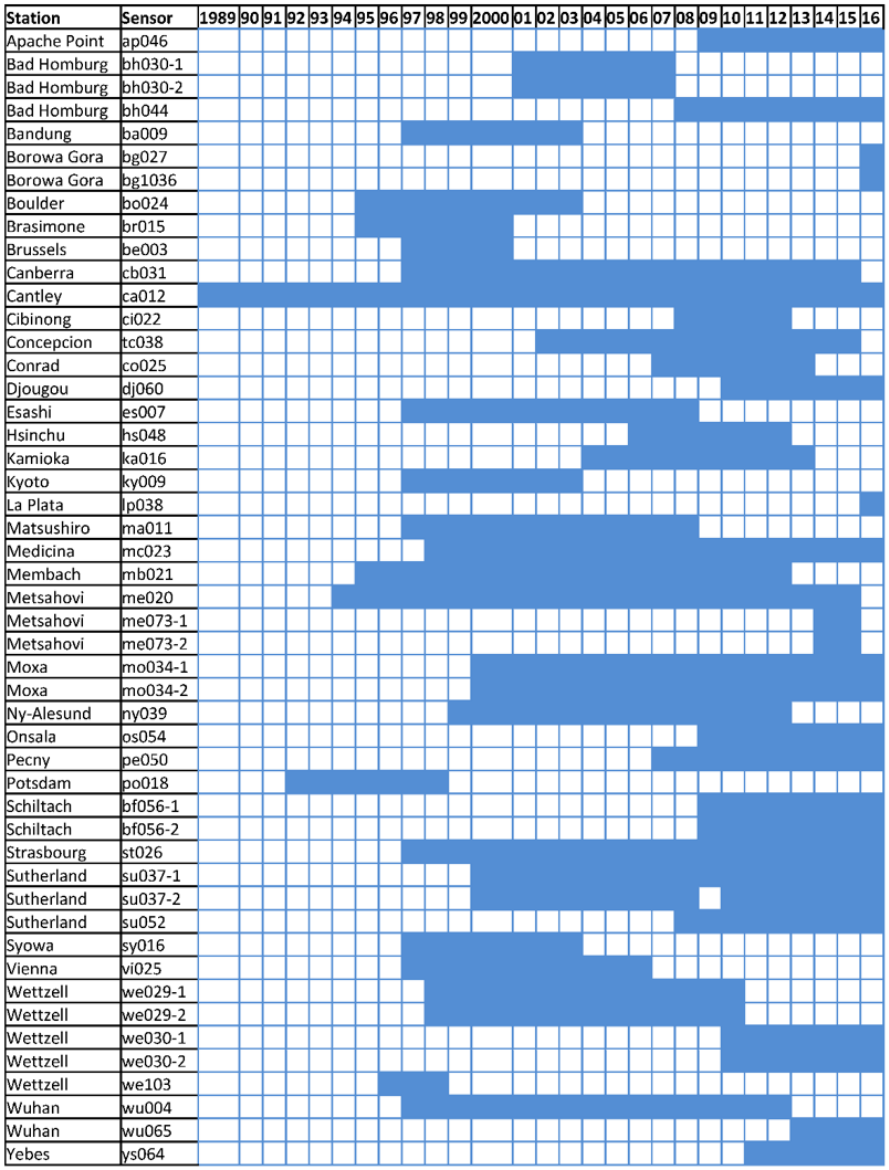
Asia:

- China (3): LH, LI, WU
- Japan (1+2): MA, [MI, IS]

Africa (1+1): SU, [DJ]

Antarctica (1): SY

Reactivation: CI (Indonesia)

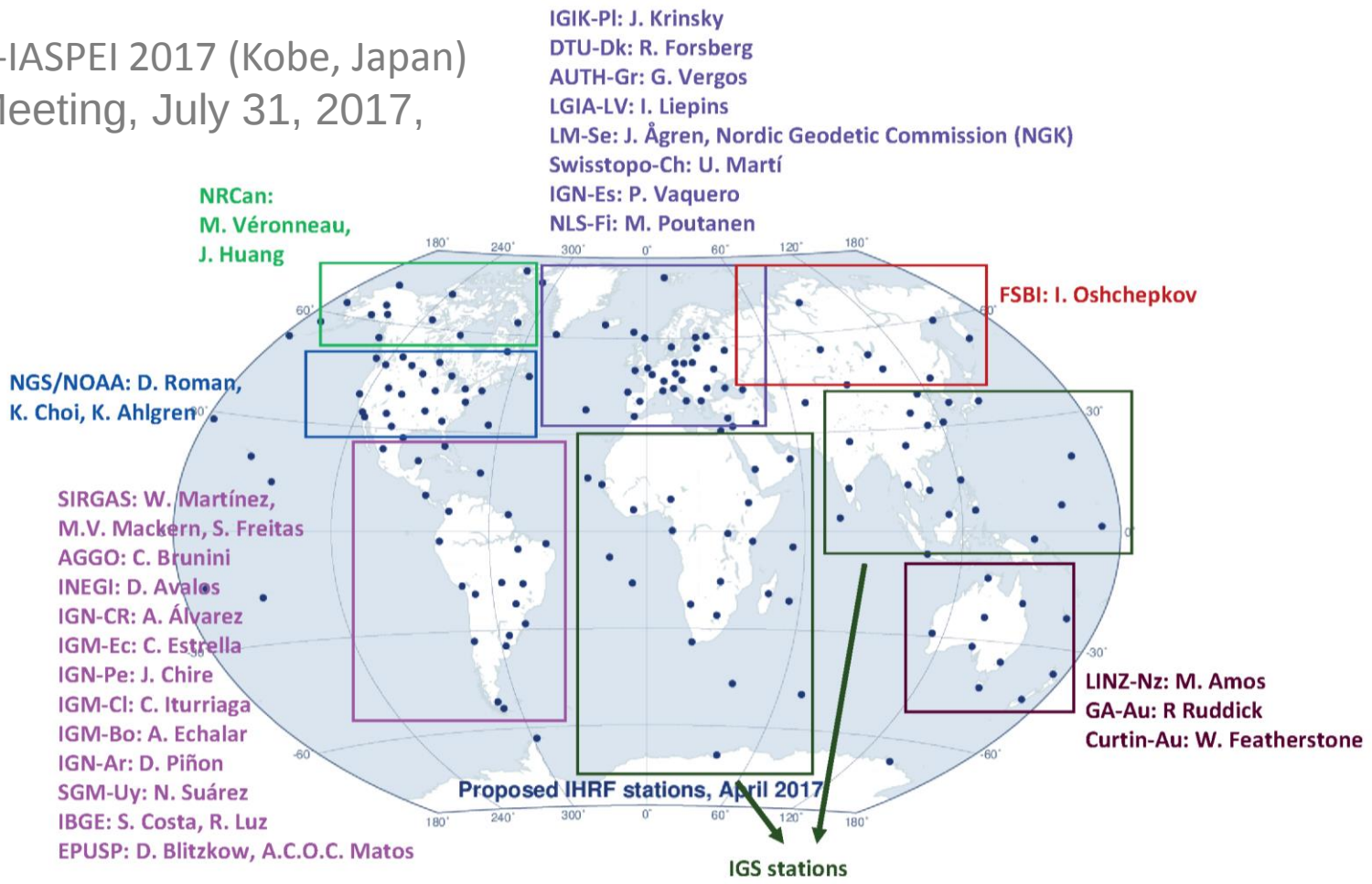


Stations if the International Height References System

First proposal for the IHRF reference network (Apr. 2017)

163 proposed stations after the feedback from the regional/national experts. In those regions with poor coverage (specially in Africa and Asia), other IGS stations were added.

Status: IAG-IASPEI 2017 (Kobe, Japan)
Business Meeting, July 31, 2017,



Poster X3.145 today!

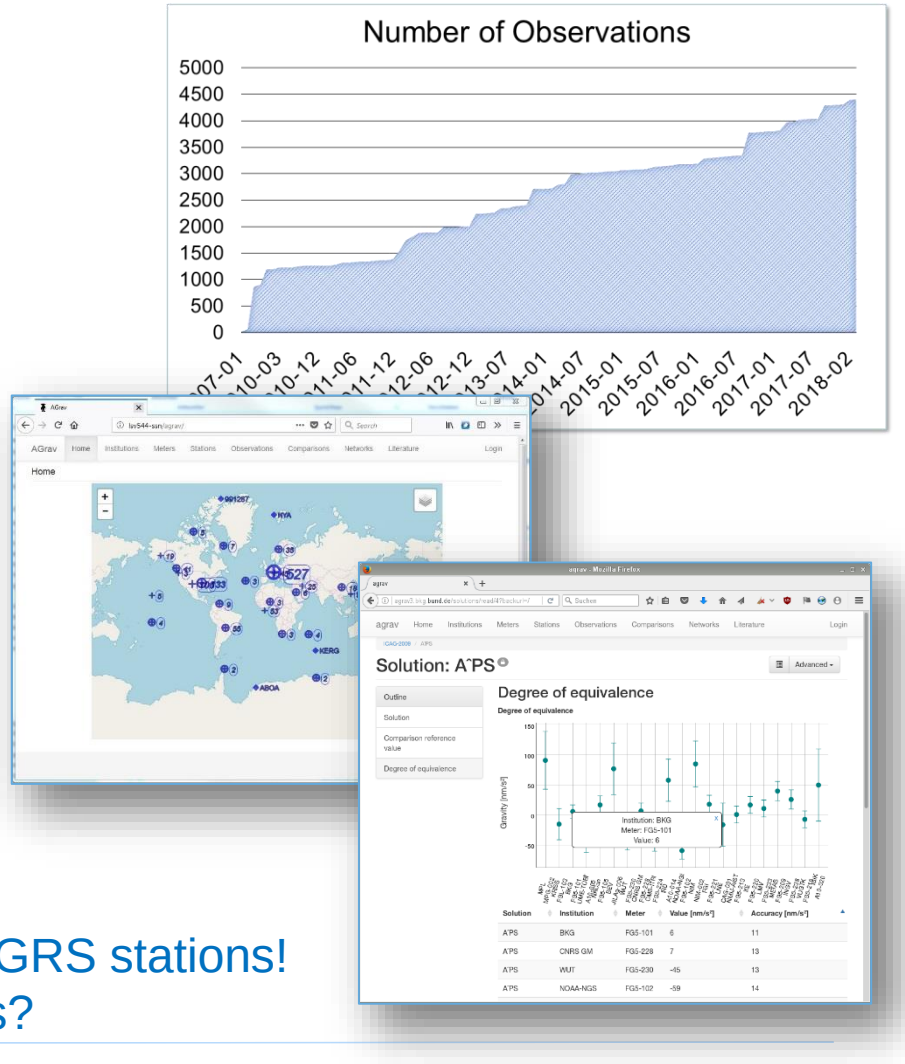
Central Inventory: AGrav database by BGI/BKG

Upgrade planned soon - New Features

- Documentation of AG comparison results, similar to BIPM KCDB
- Time series plots for AG observations at a station in common reference height
- Reports for Stations, Observations, Comparison results
- Link to IGETS

Digital Object Identifiers (DOI):

- Referencing absolute gravity observations
- First level DOI prefix retained by BGI: **`10.18168/BGI.DB_AGrav`**
- Suffixes will be derived from the AGrav database based on the primary keys, e.g. identifying data provider and station (resp. network of stations)

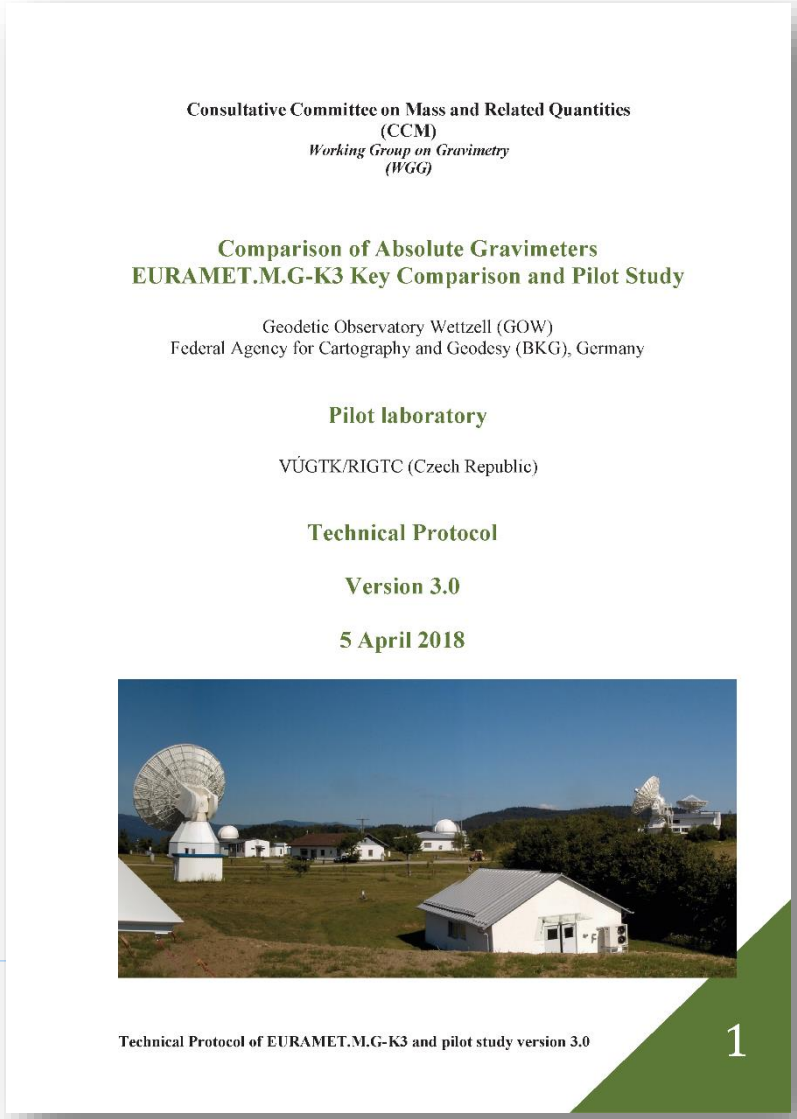


Data need to be publicly available for GAGRS stations!
Update of data policy? → Survey to users?

Comparison of Absolute Gravimeters

EURAMET.M.G-K3 Key Comparison and Pilot Study

- First EURAMET comparison at Wettzell
- Pilot laboratory:
  VÚGTK/RIGTC (Czech Republic)
- Establishing a link to CCM.G-K2.2017 (October 2017 at NIM China) for European absolute gravimeters
- Interest of Participation by ~20 teams
- Comparison based on SG over a period of 5 weeks: 16.04. - 18.05.2018
- Session 4 cancelled - week June 11-15, 2018 added


Consultative Committee on Mass and Related Quantities
(CCM)
Working Group on Gravimetry
(WGG)

Comparison of Absolute Gravimeters
EURAMET.M.G-K3 Key Comparison and Pilot Study

Geodetic Observatory Wettzell (GOW)
Federal Agency for Cartography and Geodesy (BKG), Germany

Pilot laboratory

VÚGTK/RIGTC (Czech Republic)

Technical Protocol

Version 3.0

5 April 2018

Technical Protocol of EURAMET.M.G-K3 and pilot study version 3.0 1

System vs. Frame?

Reference System:

The principles how the numbers are obtained

- Basis: Observation of the acceleration of free fall and the International System of Units (SI)
- Compatibility of the observations and its processing, including systematic effects
- Tide system (zero tide)
- Conventional models to correct temporal gravity variations

Reference Frame:

The realization of the system: the numbers actually obtained

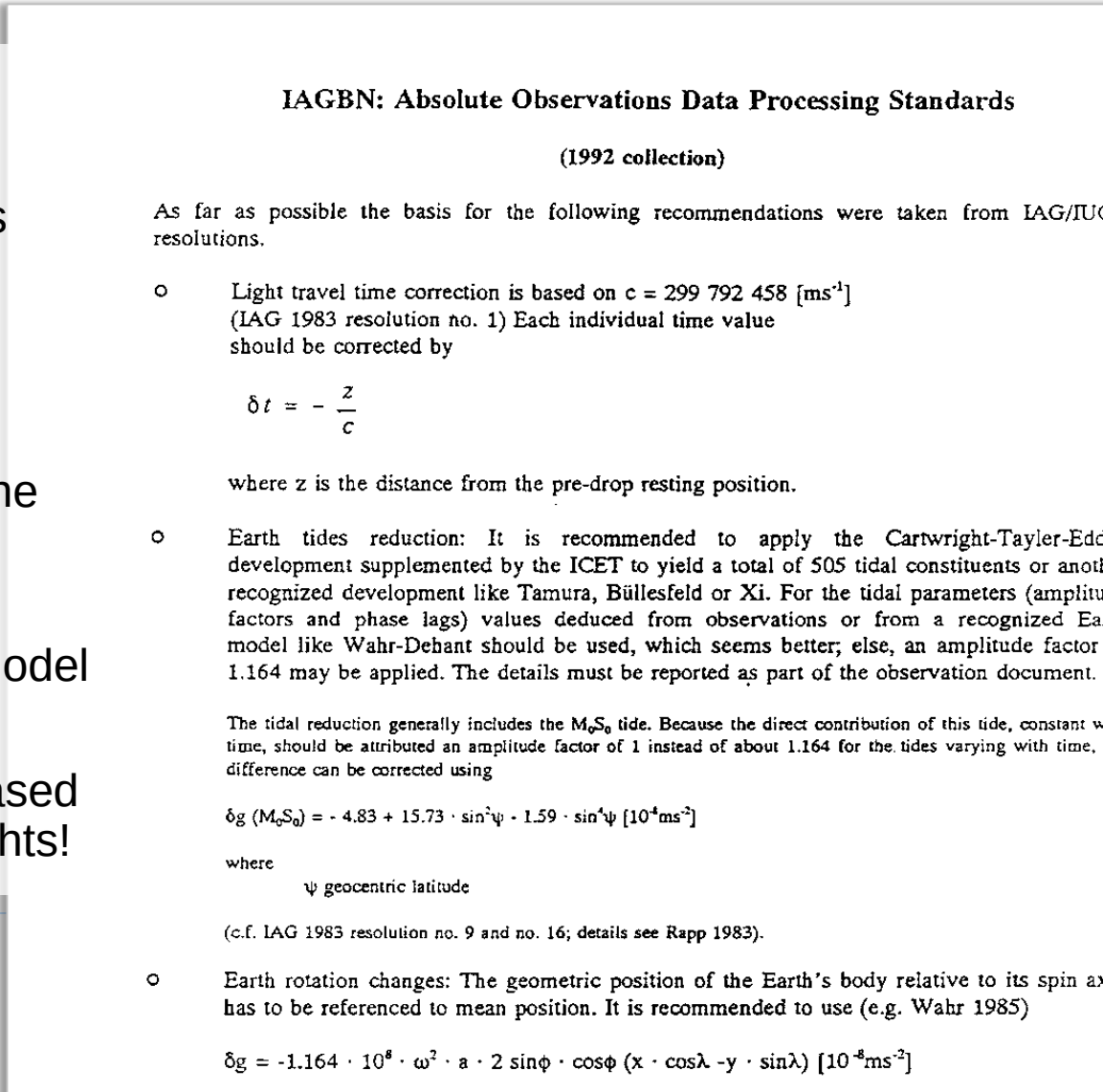
- Observations with absolute gravimeters and documentation (AGrav) Comparisons of absolute gravimeters are essential
- Traceability of the measurements to SI → comparison of absolute gravimeters
- Establishment of a compatible infrastructure (markers, points) and documentation (AGrav)

Contributions by J. Mäkinen

Update of the IAGBN Processing Standards

Talk of J. Mäkinen session G4.2 today!

- Harmonization with IERS Conventions / Recommendations of the GGOS Bureau of Standards and Conventions
- Update of constants
- Update of tidal models
- Homogenous reduction of the Permanent tide (zero tide system)
- Conventional Ocean Tide model loading:
- Atmospheric corrections, based on physical, not GNSS heights!



IAGBN: Absolute Observations Data Processing Standards

(1992 collection)

As far as possible the basis for the following recommendations were taken from IAG/IU resolutions.

- Light travel time correction is based on c = 299 792 458 [ms^{-1}] (IAG 1983 resolution no. 1) Each individual time value should be corrected by

$$\delta t = -\frac{z}{c}$$

where z is the distance from the pre-drop resting position.

- Earth tides reduction: It is recommended to apply the Cartwright-Tayler-Edd development supplemented by the ICET to yield a total of 505 tidal constituents or anot recognized development like Tamura, Büllesfeld or Xi. For the tidal parameters (amplitu factors and phase lags) values deduced from observations or from a recognized Ea model like Wahr-Dehant should be used, which seems better; else, an amplitude factor 1.164 may be applied. The details must be reported as part of the observation document.

The tidal reduction generally includes the M_0S_0 tide. Because the direct contribution of this tide, constant w time, should be attributed an amplitude factor of 1 instead of about 1.164 for the tides varying with time, difference can be corrected using

$$\delta g\,(M_0S_0) = -4.83 + 15.73 \cdot \sin^2\psi - 1.59 \cdot \sin^4\psi \;[10^{-8}\mathrm{ms}^{-2}]$$

where

ψ geocentric latitude

(c.f. IAG 1983 resolution no. 9 and no. 16; details see Rapp 1983).

- Earth rotation changes: The geometric position of the Earth's body relative to its spin ax has to be referenced to mean position. It is recommended to use (e.g. Wahr 1985)

$$\delta g = -1.164 \cdot 10^{8} \cdot \omega^2 \cdot a \cdot 2 \sin\phi \cdot \cos\phi\,(x \cdot \cos\lambda - y \cdot \sin\lambda)\;[10^{-8}\mathrm{ms}^{-2}]$$

Work Packages (cont. 2017)

1. Continuation of AG Comparisons at different Levels:
   - Further cooperation with CCM-WGG
   - Regional comparisons under guidance of Regional Metrology Organizations
   - Include non-NMI/DI instruments by Additional Comparisons
     → Documentation in AGrav
   - Stability of the comparison reference level over time:
     CRV deviations of different epochs, combination AG-SG, definition of linking converter
   - Unique processing rules (e.g. evaluation at the gradient independent point), treatment of systematic effects (SAC, DC etc.);
   - Reprocessing (since 2005)
2. Selection of Reference (Core) Stations:
   - Fixing Site requirements
   - Update of station surveys from 2011 resp. new Survey (online)

Work Packages (cont. 2017)

3. Realization of Infrastructure:
   - Evaluation of IGSN stations: Recommendation for the further use /re-observation of IGSN71 stations within the new reference system
   - New observations with AG, including field stations with A10
4. Processing Standard for absolute gravity observations:
   Update of the IAGBN standards 1992

Outlook

- Setup of a dedicated Webpage (BGI/BKG)
- Installation of a Analysis Center (homogeneous reprocessing)?
- Name / Abbreviation? (Subject of discussion at SC2 meeting in Kobe)
- Workshop?
- Further Discussion: Forum
  http://agrav.bkg.bund.de/forum/

Continue Discussion at Poster X3.146 today!