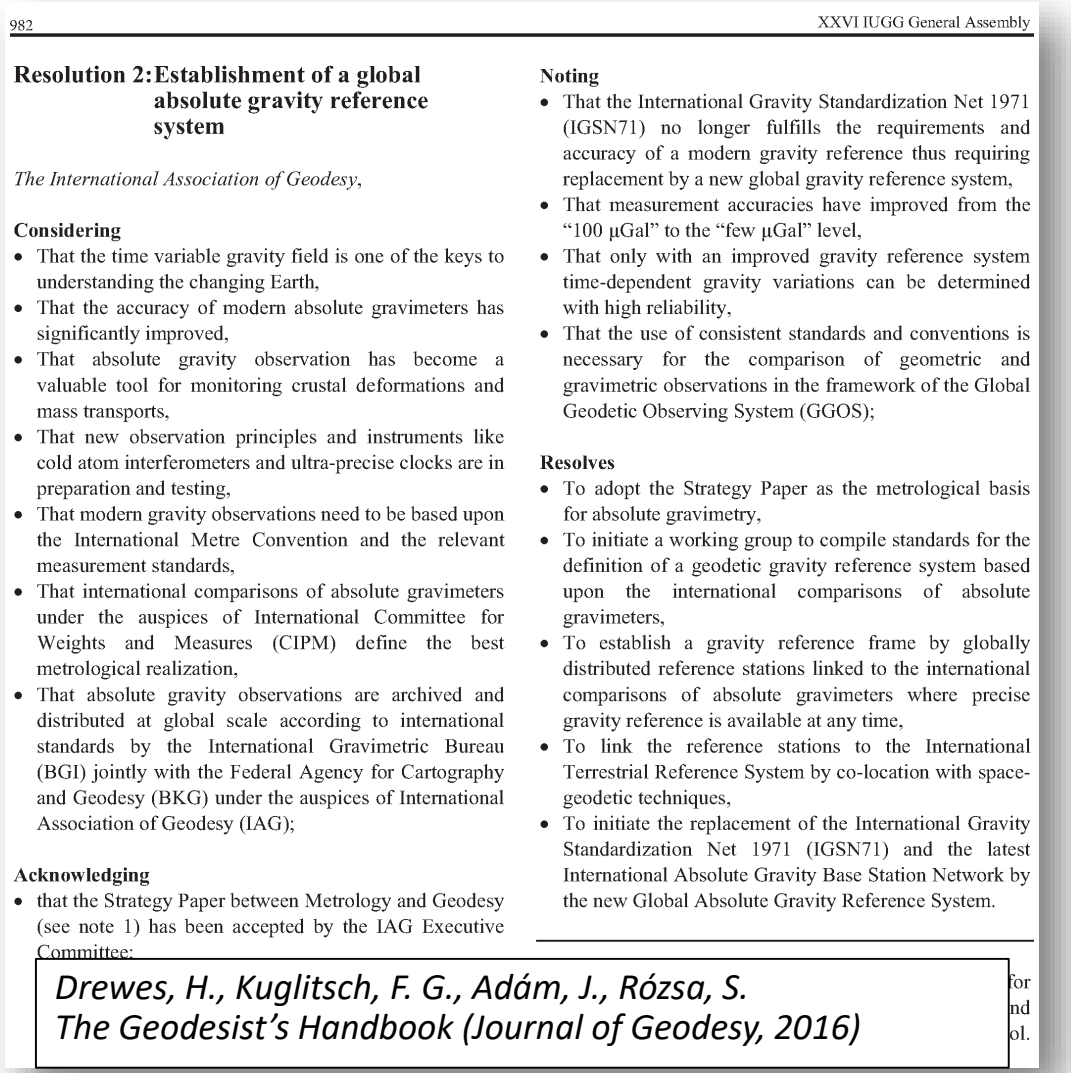
Proposal for an IAG resolution on the International Terrestrial Gravity Reference System

Webmeeting of IAG Joint Working Group 2.1.1
Thursday, May 11th 2023

Chair: **Hartmut Wziontek**, BKG (Germany)
Vice-chair: Sylvain Bonvalot, BGI (France)

Establishment of a global absolute reference system

IAG Resolution No. 2 (2015)



982 XXVI IUGG General Assembly

Resolution 2: Establishment of a global absolute gravity reference system

The International Association of Geodesy,

Considering

- That the time variable gravity field is one of the keys to understanding the changing Earth,
- That the accuracy of modern absolute gravimeters has significantly improved,
- That absolute gravity observation has become a valuable tool for monitoring crustal deformations and mass transports,
- That new observation principles and instruments like cold atom interferometers and ultra-precise clocks are in preparation and testing,
- That modern gravity observations need to be based upon the International Metre Convention and the relevant measurement standards,
- That international comparisons of absolute gravimeters under the auspices of International Committee for Weights and Measures (CIPM) define the best metrological realization,
- That absolute gravity observations are archived and distributed at global scale according to international standards by the International Gravimetric Bureau (BGI) jointly with the Federal Agency for Cartography and Geodesy (BKG) under the auspices of International Association of Geodesy (IAG);

Acknowledging

- that the Strategy Paper between Metrology and Geodesy (see note 1) has been accepted by the IAG Executive Committee;

Noting

- That the International Gravity Standardization Net 1971 (IGSN71) no longer fulfills the requirements and accuracy of a modern gravity reference thus requiring replacement by a new global gravity reference system,
- That measurement accuracies have improved from the "100 μGal" to the "few μGal" level,
- That only with an improved gravity reference system time-dependent gravity variations can be determined with high reliability,
- That the use of consistent standards and conventions is necessary for the comparison of geometric and gravimetric observations in the framework of the Global Geodetic Observing System (GGOS);

Resolves

- To adopt the Strategy Paper as the metrological basis for absolute gravimetry,
- To initiate a working group to compile standards for the definition of a geodetic gravity reference system based upon the international comparisons of absolute gravimeters,
- 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,
- To link the reference stations to the International Terrestrial Reference System by co-location with space-geodetic techniques,
- To initiate the replacement of the International Gravity Standardization Net 1971 (IGSN71) and the latest International Absolute Gravity Base Station Network by the new Global Absolute Gravity Reference System.

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Drewes, H., Kuglitsch, F. G., Adám, J., Rózsa, S.
The Geodesist's Handbook (Journal of Geodesy, 2016)

Key points

- ✓ **IGSN71 no longer fulfills the requirements and accuracy** for the understanding of the Earth's system, metrology…
- ✓ **Measurement accuracy has improved** from the 100 μGal to « few μGal » level
- ✓ Needs for **consistent standards & conventions** of geometric and gravimetric observations (GGOS framework)

- ➢ Network of globally distributed stations where precise gravity reference is available at any time
- ➢ Link to International Terrestrial Reference Frame
- ➢ Initiate the replacement of IGSN71 and IAGBN

Establishment of ITGRF infrastructure

IAG Resolution No. 4 of 2019

Resolution 4: Establishment of the Infrastructure for the International Gravity Reference Frame

The International Association of Geodesy,

Considering,

- The IAG Resolution No. 2 for the establishment of a global absolute gravity reference system released at the 26th IUGG General Assembly in July 2015;

Acknowledging,

- The achievements of
  - JWG 2.1.1 "Establishment of a global absolute gravity reference system",
  - Sub-Commission 2.1 "Gravimetry and Gravity Networks",
  - International Gravity Field Service (IGFS)
- in realizing this resolution;

Noting,

- That the realization of the International Gravity Reference System (IGRS), the International Gravity Reference Frame (IGRF), is based on measurements with absolute gravimeters (AG) monitored at reference stations and during international comparisons, which needs the support of national and international institutions;

Urges,

- International and national institutions, agencies and governmental bodies in charge of geodetic infrastructure to
  - Establish a set of absolute gravity reference stations on the national level,
  - Perform regular absolute gravity observations at these stations,
  - Participate in comparisons of absolute gravimeters to ensure their compatibility,
  - Make the results available open access.

27th IUGG General Assembly
Assemblée Générale de l'UGGI
IUGG UGGI
July 8 – 18 2019, Montréal, Canada

- ITGRF is realized by measurements with absolute gravimeters at any time
- To make the ITGRF accessible to stakeholders and to finally replace IGSN71, an adequate infrastructure based on absolute gravity measurements needs to be built up.
- Support of international and national institutions, agencies and governmental bodies in charge of geodetic infrastructure is required to
  - ➢ Establish compatible first order gravity networks
  - ➢ Provide information about existing absolute gravity observations
  - ➢ Participate in AG comparisons

Previous Resolutions

***Hamburg 1983**: IAG RESOLUTION No. 9:* **Tides / Atmosphere**

https://office.iag-aig.org/doc/5d7b8fda34fe2.pdf

The International Association of Geodesy,

recognizing the high level of accuracy of both absolute and relative gravity measurements recently attained,

considering the necessity to adopt standard corrections to gravity observations in order to allow intercomparisons between measurements at different epochs of time,

recommends :

1. that the *tidal correction* applied to the gravity observations follow the final recommendations of the Standard Earth Tide Committee as presented at the XVIII IUGG General Assembly,
2. that the *atmospheric pressure corrections* refer to a common Standard Atmosphere, the sensitivity coefficient being $0.3 \cdot 10^{-10}$ m s^{-2}/Pa (0.3 microga]/mbar), unless it is determined by special investigations, in which case the value used must be published together with the results. The closed formula for the computation of this Standard Atmosphere will be published in a future issue of the Bulletin d'l nformation du Bureau Gravimétrique International with the corresponding numerical tables and the programming code.
3. that the gravity *gradient corrections* be published with the adopted local gradient and/or the adopted height difference so that the original values may be recovered.

***Hamburg 1983**: IAG RESOLUTION No. 16 1983:* **Permanent Tide**

The International Association of Geodesy,

recognizing the need for the uniform treatment of tidal corrections to various geodetic quantities such as gravity and station positions, and

considering the reports of the Standard Earth Tide Committee and S.S.G. 2.55 Predictive Methods for Space Techniques, presented at XVIII General Assembly,

recommends that :

1. the rigid Earth model be the Cartwright -- Tayler -- Edden model with additional constants specified by the International Centre for Earth Tides,
2. the elastic Earth model be that described by Wahr using the 1066 A model Earth of Gilbert and Dziewonski,
3. the indirect effect due to the permanent yielding of the Earth be not removed,

and

4. ocean loading effects be calculated using the tidal charts and data produced by Schwiderski as working standards.

Draft Resolution

IAG is

Noting

- The importance of an International Terrestrial Gravity Reference System (ITGRS) for geodesy and geosciences.
- That the relative accuracy achievable with state-of-the-art absolute gravimeters is now a few parts in 10^9

Acknowledging

- The IAG Resolution No. 2 for the establishment of a global absolute gravity reference system released at the 26th IUGG General Assembly in Prague in July 2015.
- The IAG Resolution No. 4 on the establishment of the Infrastructure for the International Terrestrial Gravity Reference Frame, released at the 27th IUGG General Assembly in Montreal in July 2019.
- The IAG resolution No. 9.2 adopted at the 18th IUGG General Assembly in Hamburg in August 1983, recommending the use of a standard atmosphere.
- The IAG resolution No. 16.3 adopted at the 18th IUGG General Assembly in Hamburg in August 1983, recommending the zero-tide concept.

International *Terrestria*l Gravity Reference System and Frame (ITGRS / ITGRF)

Reference System:

The fundamental principles

Stable definition of gravity

- Measurand: **Instantaneous acceleration of free-fall**, expressed in the International System of Units (SI)
- Set of conventional models for the time dependent corrections, comprising **constant components**:
  - Zero-tide system for the tidal correction
  - Standard atmosphere ISO 2533:1975 (DIN 5450) for the correction for atmospheric gravity effects
  - Reference pole of the International Earth Rotation and Reference Systems Service (IERS) for the correction for polar motion.

→ **Conventional quantity „acceleration of gravity"**

Reference Frame:

The realization of the system

Compatibility of gravity measurements

The realization of the ITGRS, subject to model improvements or updated requirements and represented by

- **Absolute gravity measurements** traceable to the International System of Units (SI) (time and frequency)
- **Common reference level** and traceability to the SI: Absolute Gravimeters have to be checked at comparisons / by calibration
- Models for temporal gravity corrections: **IGRS 2020 Conventions**
- **Global set of reference stations** with reliable absolute gravity values (**relative accuracy of 10^{-8} and better**) and monitoring capabilities for temporal changes

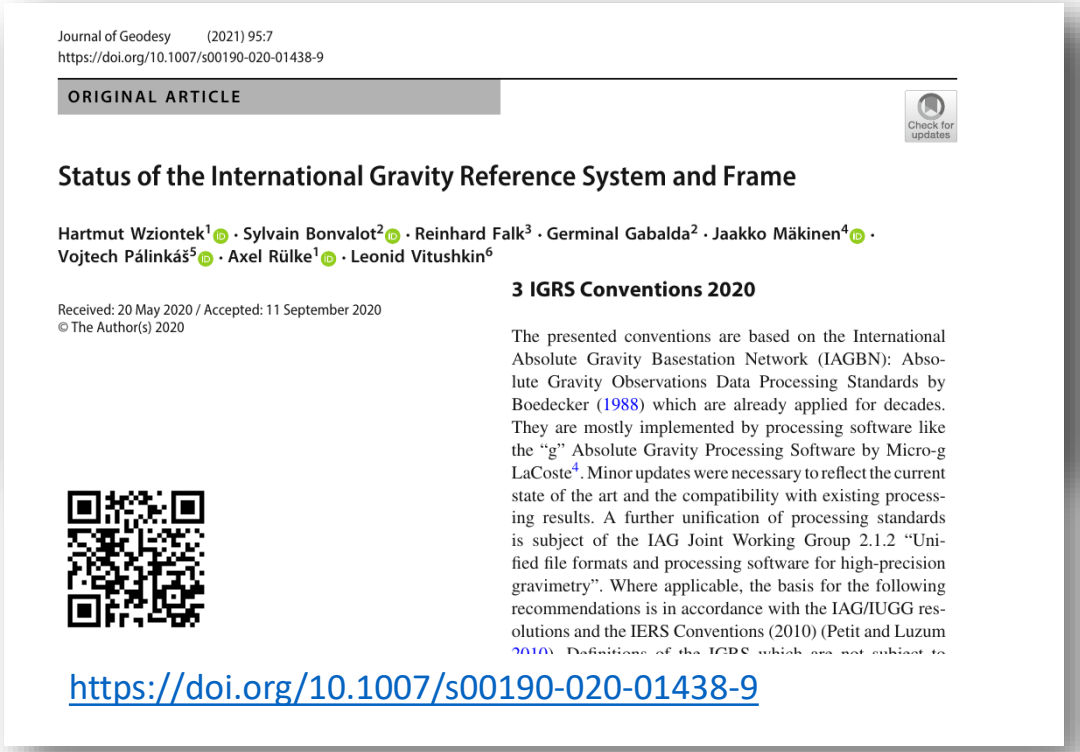
IGRS Conventions 2020 (1)

Conventional models (minimum requirements) for the correction of temporal gravity changes

Based on and compatible with International Absolute Gravimeter Base Network (IAGBN) Processing Standards, Boedecker (1988)

- Tides:
  Permanent tide: Zero-tide system
  Tide generating potential: Tamura (or higher development);
  Elastic response: Observed tidal parameters or *Earth model of Dehant, Defraigne and Wahr (1999) (DDW)*
- Atmosphere:
  Standard Atmosphere: DIN 5450 (ISO 2533:1975),
  Temporal variations: *air pressure admittance: 3 nm/s²/hPa*
- Polar motion:
  IERS reference pole with *elastic gravimetric factor 1.164*
- Ocean tide loading:
  FES2004 or best fitting model

Legend: retained | improved | system | *frame*



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ORIGINAL ARTICLE

Check for updates

Status of the International Gravity Reference System and Frame

Hartmut Wziontek[1] · Sylvain Bonvalot[2] · Reinhard Falk[3] · Germinal Gabalda[2] · Jaakko Mäkinen[4] · Vojtech Pálinkáš[5] · Axel Rülke[1] · Leonid Vitushkin[6]

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3 IGRS Conventions 2020

The presented conventions are based on the International Absolute Gravity Basestation Network (IAGBN): Absolute Gravity Observations Data Processing Standards by Boedecker (1988) which are already applied for decades. They are mostly implemented by processing software like the "g" Absolute Gravity Processing Software by Micro-g LaCoste[4]. Minor updates were necessary to reflect the current state of the art and the compatibility with existing processing results. A further unification of processing standards is subject of the IAG Joint Working Group 2.1.2 "Unified file formats and processing software for high-precision gravimetry". Where applicable, the basis for the following recommendations is in accordance with the IAG/IUGG resolutions and the IERS Conventions (2010) (Petit and Luzum

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Proposal of an IAG resolution 2023 (a)

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→ **Conventional quantity „acceleration of gravity"**

Adopts the ITGRS as the preferred gravity system based on

the instantaneous acceleration of free-fall expressed in SI

and

related to the zero-tide concept,

a standard atmosphere and

Earth Orientation in the ITRS.

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Adopts the ITGRS as the preferred gravity system based on the instantaneous acceleration of free-fall expressed in SI and related to the zero-tide concept, a standard atmosphere and Earth Orientation in the ITRS.

Next steps?

- Send proposal to SC2.1 / Commission 2
- Present to IAG Resolution Committee at IUGG 2023 in Berlin