Towards the implementation of the International Gravity Reference System in Poland

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IGiK

Presentation overview

- *International Gravity Reference System*
  - *Motivation*
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- *International Gravity Reference Frame*
  - *Infrastructure*
- *IGRF infrastructure in Poland*
  - *Polish Gravity Control*
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International Gravity Reference System

Motivation:

IAG Resolution No. 2 (2015): Establishment of a global absolute gravity reference system

…

Noting:

…

- that the International Gravity Standardization Net 1971 (IGSN71) **no longer fulfils 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 improved gravity reference system time-dependent gravity variations can be determined with **high reliability,**

…

Recommends:

…

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

International Gravity Reference System

Motivation:

IAG Resolution No. 4 (2019): Establishment of the Infrastructure for the International Gravity Reference Frame

…

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**.

International Gravity Reference System

Reference system:

The fundamental principles: The definition of gravity must be stable over time.

Measurand:

Instantaneous acceleration of free-fall expressed in the International System of Units (SI)

Set of conventional corrections

- Zero-tide system
- Standard atmosphere ISO 2533:1975
- Earth rotation axis IERS reference pole define the conventional quantity “acceleration of gravity”

Reference:

Wziontek H., Bonvalot S., Falk R. et al. Status of the International Gravity Reference System and Frame. J Geod ***95,*** *7 (2021). https://doi.org/10.1007/s00190-020-01438-9*

International Gravity Reference Frame

Reference frame:

The realization of the system: The numbers actually obtained

- **Observations with absolute gravimeters**: (epoch, position, gravity, vertical gravity gradient, reference height)
- **Comparisons of absolute gravimeters**: traceability and compatibility of the observations and the processing, assessment of systematic effects
- **Set of conventional models** for correction of temporal changes (tides, ocean tide loading, atmosphere, polar motion) - **IGRS Conventions 2020**
- **Compatible infrastructure** (markers, points) and documentation (database)

Reference:

Wziontek H., Bonvalot S., Falk R. et al. Status of the International Gravity Reference System and Frame. J Geod ***95,*** *7 (2021). https://doi.org/10.1007/s00190-020-01438-9*

International Gravity Reference Frame

Reference frame:

Infrastructure:

- **Reference stations** are essential to ensure a long-term stable absolute gravity reference
  - ➢ Continuous operation of a superconducting gravimeter in combination with repeated absolute gravity observations
  - ➢ Continuously operated absolute quantum gravimeter
  - ➢ Repeated absolute gravity observations (two months interval recommended)
- **Comparison stations** are reference stations as described above with extended facilities to check the compatibility of instruments, either based on continuous gravity monitoring or by simultaneous measurements of at least two absolute gravimeters.
- **Core stations** provide a link to the ITRF where at least one space geodetic technique is established and GGOS core sites play an essential role.

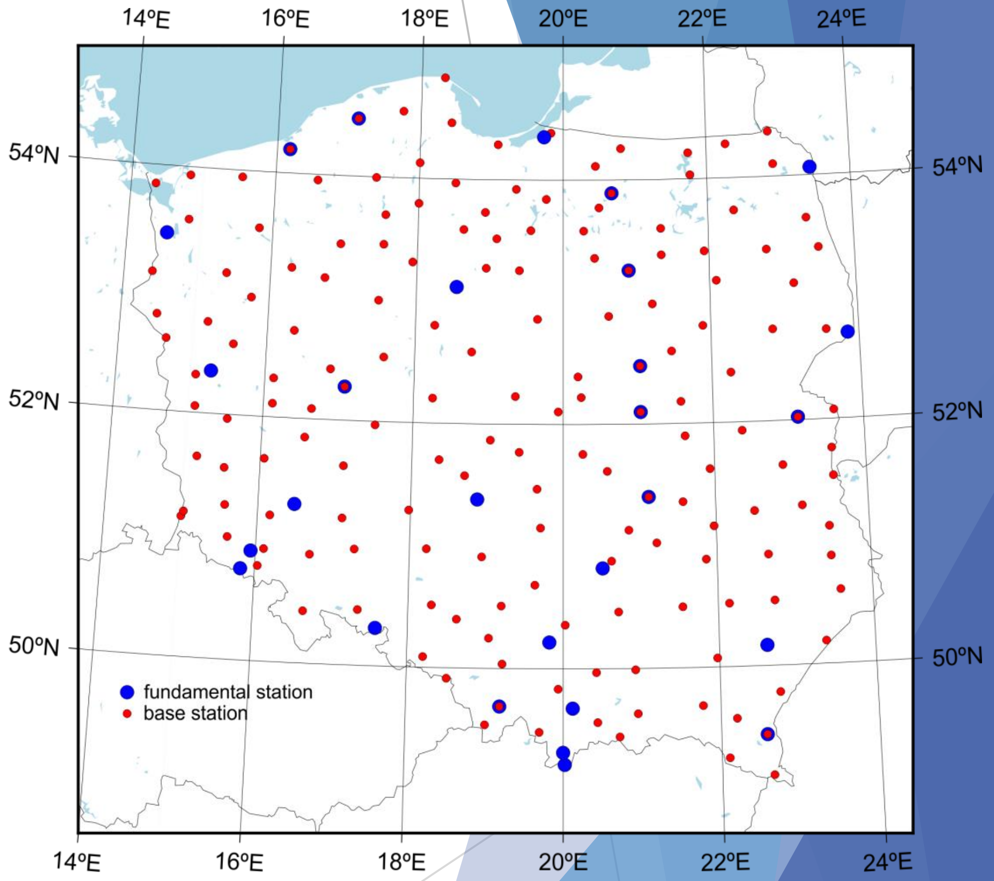
Reference:

Wziontek H., Bonvalot S., Falk R. et al. Status of the International Gravity Reference System and Frame. J Geod ***95,*** *7 (2021). https://doi.org/10.1007/s00190-020-01438-9*

IGRF infrastructure in Poland

Polish Gravity Control established in 2011-2015:

- Absolute gravity stations
  - 28 fundamental stations – indoor (FG5-230)
  - 168 base stations – outdoor (A10-020)
  - All stations with determined VGGs
- Quality control
  - Regular absolute gravity surveys at Borowa Gora (A10-020) and Jozefoslaw (FG5-230)
  - Gravimeter calibrations (laser, clock, barometer)
  - Local gravimeter comparisons (A10-020 to FG5-230)
  - International Comparisons of Absolute Gravimeters (ICAG2011, ECAG2013, ECAG2015) – **link to the international gravity reference level**
- Defined correction models
- Gravity control is up for „review" within next couple of years

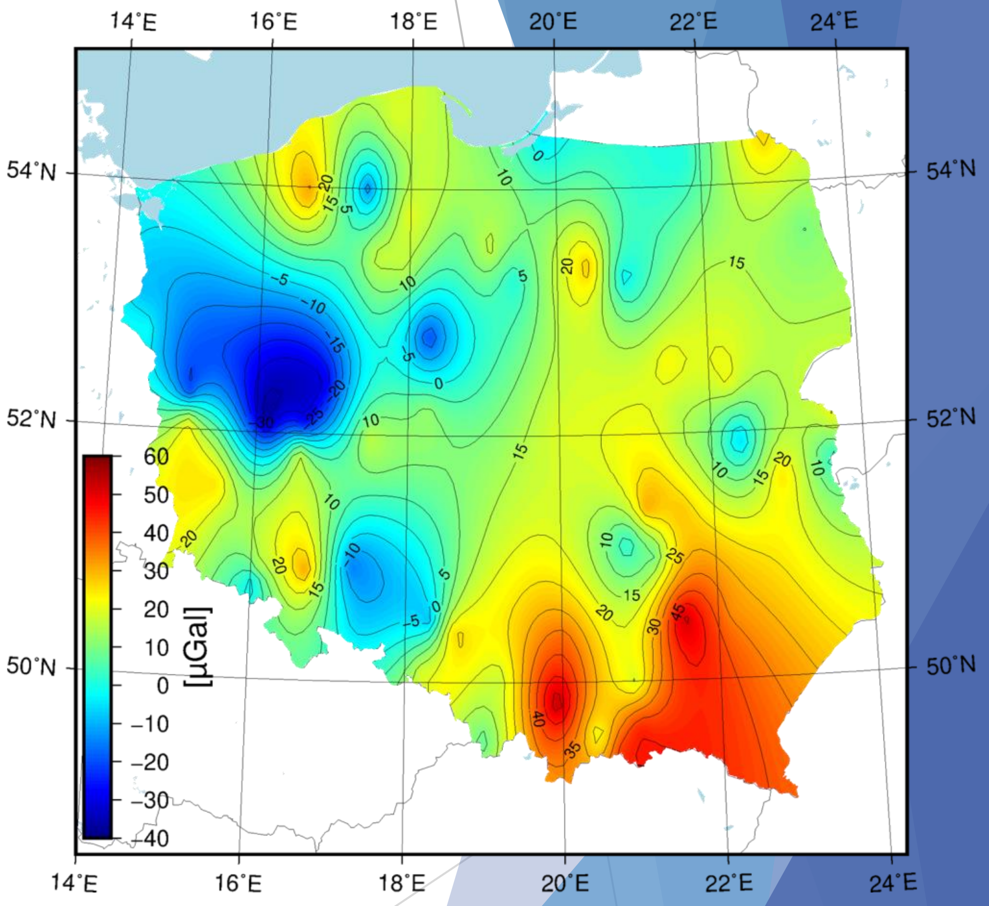


In principle gravity control was established consistently the IGRS Conventions 2020

IGRF infrastructure in Poland

Polish Gravity Control established in 2011-2015:

- Absolute gravity stations
  - 28 fundamental stations – indoor (FG5-230)
  - 168 base stations – outdoor (A10-020)
    - ✓ 78 POGK
    - ✓ 22 POLREF
    - ✓ 4 EUVN
    - ✓ 57 ASG-EUPOS eccentric stations
    - ✓ 7 new stations
- Relation to POGK99 gravity control (established in 1990s)
  - Based on 78 stations
  - **Gravity differences ranging from -400 to +600 nm/s^2 (-40 to +60 µGal)**



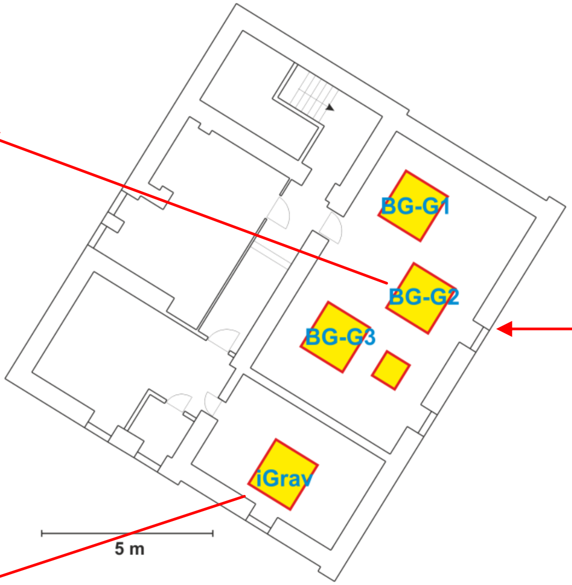
Confirming the need for periodic gravity control review/evaluation/re-measurement

IGRF infrastructure in Poland

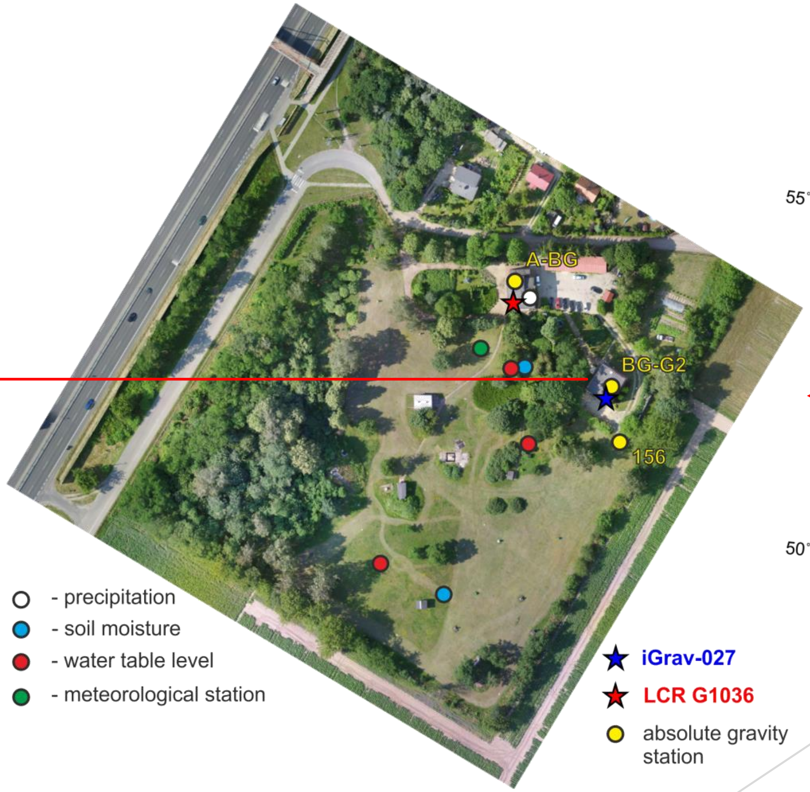
Borowa Gora Geodetic-Geophysical Observatory

- located ~35 km north of Warsaw
- owned by the Institute of Geodesy and Cartography

Gravimetric Laboratory



Borowa Gora Geodetic-Geophysical Observatory

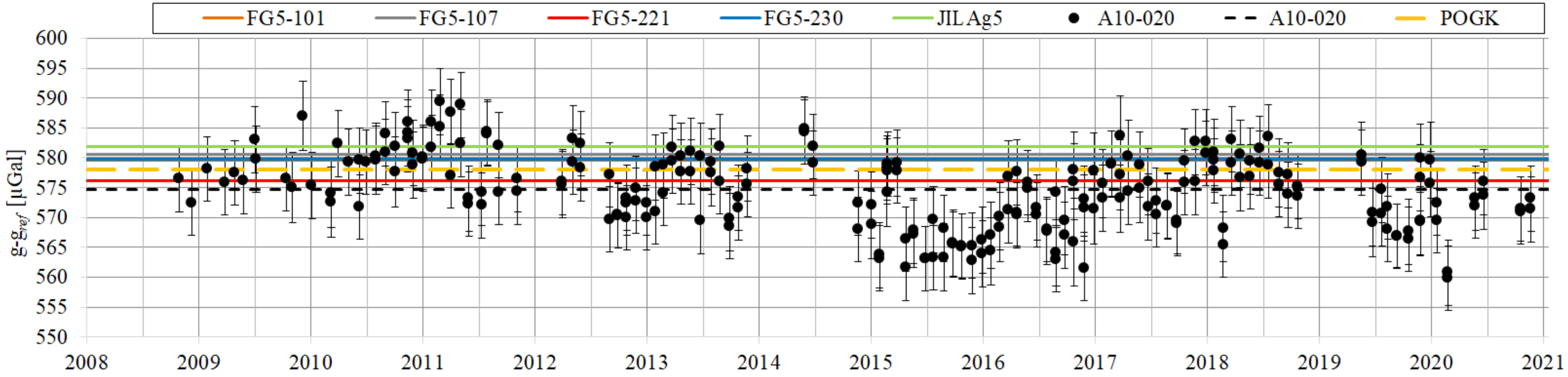


IGRF infrastructure in Poland

Borowa Gora Geodetic-Geophysical Observatory:

Since 2008 – regular monthly **A10-020 gravity surveys** on three stations, supplemented with:

- **Gravimeter calibrations** (laser, clock, barometer) at the Central Office of Measures (at least once a year)
- Participation in the **international absolute gravimeter comparisons**: ICAG2009, ECAG2011, ICAG2013, ECAG2015, ECAG2018
- **Local comparisons** of absolute gravimeters: A10-020 with FG5-230 (once a year)

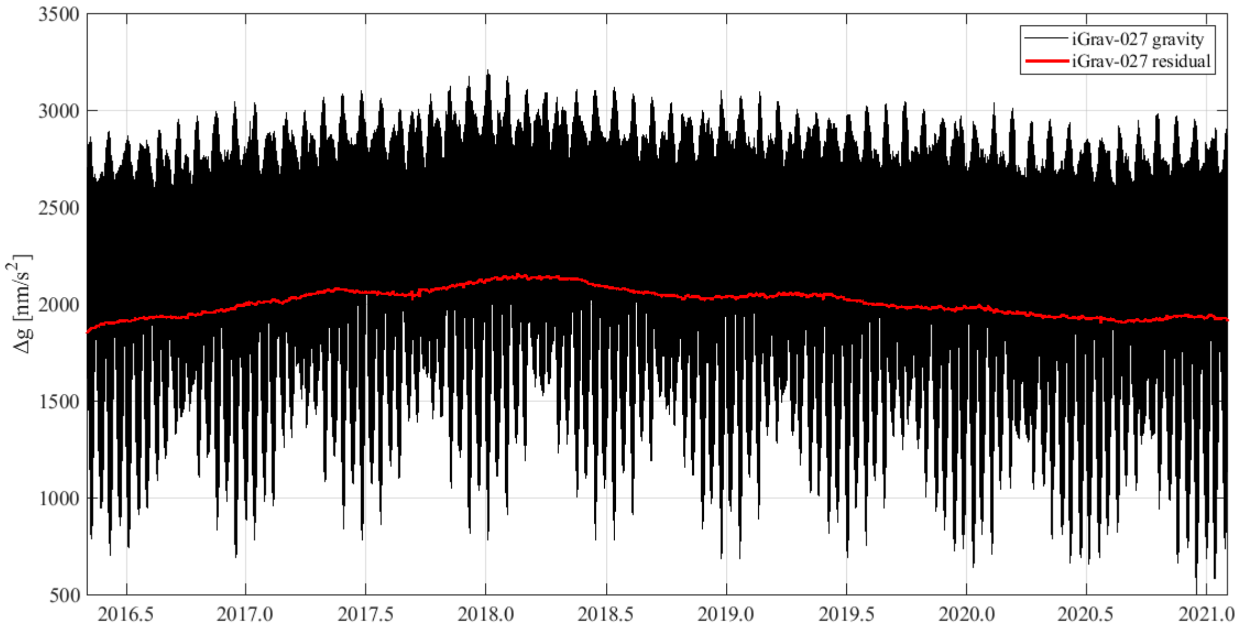


IGRF infrastructure in Poland

Borowa Gora Geodetic-Geophysical Observatory:

<u>**Since 2016**</u> – continuous **records with the iGrav-027** superconducting gravimeter, supplemented with:

- **Scale factor determinations** using absolute (A10-020, FG5-230) and relative gravimeters
- **Repeated A10-020** absolute gravimeter **measurements** as well as several FG5-230 surveys
- Various meteorological and hydrological sensors

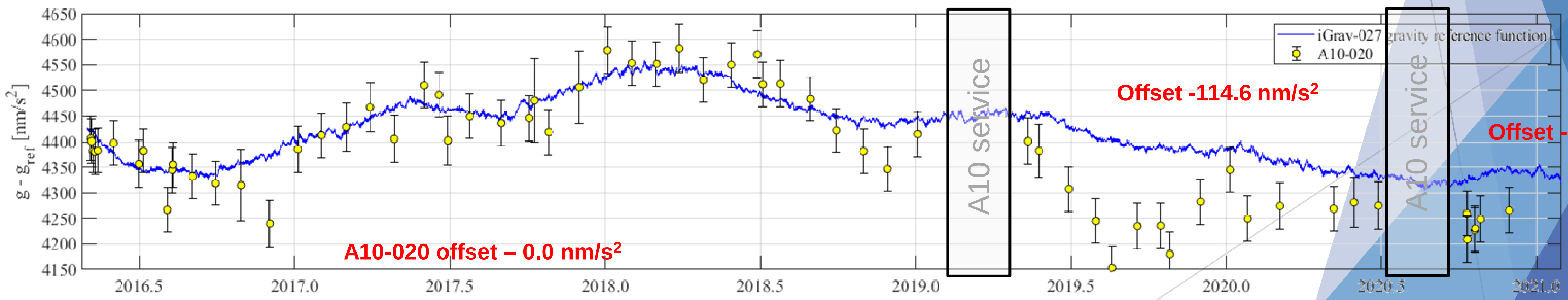


IGRF infrastructure in Poland

Borowa Gora Geodetic-Geophysical Observatory:

Since 2016 – joint analysis of A10-020 and iGrav-027 results, resulting in:

- **Drift evaluation** for the iGrav-027 superconducting gravimeter
- **Repeatability/long term stability** analysis for the A10-020 absolute gravimeter at the level of **30-40 nm/s^2 (3-4 µGal)**
- Evaluation of the **gravity reference function** at the Borowa Gora Observatory using A10-020 offsets from ECAG2015 and RCAG2018 gravimeter comparisons (KC solution) – peak to peak ~**200 nm/s^2 (20 µGal)**
- **Reliable gravity reference** provided for the A10-020 gravimeter for repeated gravity surveys within the **EPOS-PL project,** the establishment of AGN Ireland (collaboration with Ordnance Survey Ireland) as well as all upcoming work



Gravity reference function at the Borowa Gora Observatory; g_{ref} = **9 812 500 000 nm/s^2**

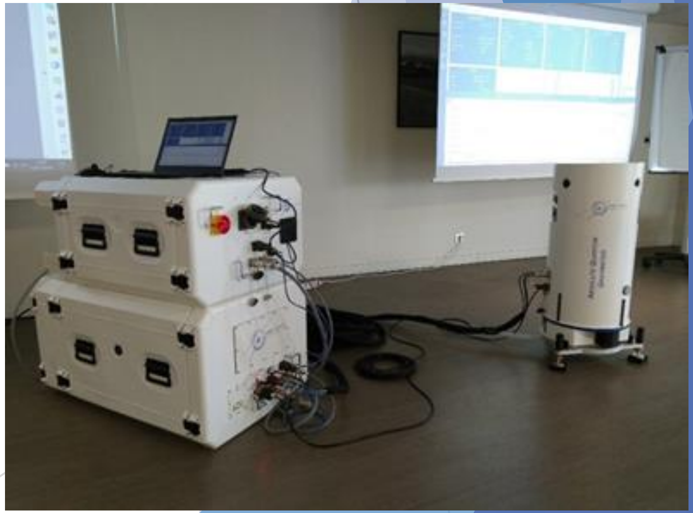
IGRF infrastructure in Poland

Borowa Gora Geodetic-Geophysical Observatory capabilities:

- Possibility to perform small scale **absolute gravimeter comparisons** (up to 3 instruments)
- Possibility to link the absolute gravity surveys to the **gravity reference function**
- Further extension of Borowa Gora and IGiK capabilities with the acquisition of the **absolute quantum gravimeter (AQG)** (planned for late 2021)

Advantages of maintaining a gravity reference function:

- Evaluation of an absolute gravimeter **repeatability/long term stability**
- **Relation to the international mean gravity reference level** in between instrumental maintenance, limited possibilities for AG comparisons (i.e. Covid-19 restrictions), which is crucial for the reliability of all performed absolute gravity surveys



Summary

- **International Gravity Reference System** is underway to become the official gravity reference system, which **needs preparations** upfront as well as **support** of international and national institutions, agencies and governmental bodies in charge of geodetic infrastructure which is described in IAG resolution No. 4 of 2019
- Borowa Gora Observatory is actively working towards becoming a **reference and comparison station** of the IGRS/IGRF
- Still **AG comparisons are crutial**, at least to **verify/validate the gravity reference function** at the Borowa Gora Observatory
- Maintaining a gravity reference function poses significant advantages in terms of establishing and maintaining gravity reference frames, reliable monitoring of time variable gravity changes
- Acquisition of the Absolute Quantum Gravimeter is expected to strengthen the capabilities of IGiK in terms of gravity reference maintenance

Invitation:

Any interested absolute gravimeter users/institutions are welcome to visit Borowa Gora to verify the operationability of their instrument, and simultaneously to contribute to validation of the reference function at Borowa Gora

Acknowledgements:

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