International Gravimetric Bureau – Bureau Gravimétrique International (BGI)

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Director: Sylvain Bonvalot (France)

BGI website - http://bgi.obs-mip.fr

1 Introduction

The Bureau Gravimétrique International (BGI) was created in 1951 during the IUGG General Assembly as a scientific Service of the IAG for ensuring the collection, validation, archiving of all gravity measurements acquired at the Earth surface and their distribution to scientific users. The technological and scientific evolutions which took place over the following decades in the area of gravimetry (improvements in field, airborne and seaborne gravity meters, development of absolute gravity meters, space gravity missions, etc.) have led to a significant increase of the number, diversity and accuracy of the gravity field observables. Following these evolution, the BGI has contributed to original databases and services (products, documentation, tutorials, software) for a wide international community concerned with the studies of the Earth gravity field. The BGI has been set up in France (Paris, then Toulouse) and has benefited from the recognition by the International Science Council (ISC) as one of the Services of the Federation of Astronomical and Geophysical Services (FAGS).

Today, the BGI is an official IAG Service and contributes with the other Services to IAG Commissions and Working Groups and to the GGOS.

Before the era of the satellite gravity missions, the BGI has played a major role in supporting the computation of global and regional models of the Earth's gravity field, primarily based on terrestrial gravity measurements together with Satellite Laser Ranging (SLR) data. It has also provided accessibility to the global network of stations for referencing the worldwide gravity data surveys in a same absolute reference system

(Potsdam and IGSN71 networks). Today, relative and absolute gravity measurements, derived from field surveys (land, airborne and seaborne), monitoring networks and laboratory experiments, provide unprecedented precision and accuracy on the spatial and temporal variations of the Earth's gravity field. They remain fundamental in many issues such as the determination of the short wavelengths of the Earth gravity, the calibration/validation of the results derived from satellite observations or from other relative gravity observations, and the definition of the global Earth gravity reference frame. They serve a wide range of applications in Planetary, Solid Earth, Oceanography, Atmospheric, Hydrologic sciences and metrology, for instance.

The BGI operates within IAG in close collaboration with the other gravity Services (ISG, ICGEM, IDEMS, IGETS), with IGFS COST-G, and is strongly committed in the activities of GGOS, of Commission 2 - Gravity Field and in several IAG Working Groups related to the determination of the Earth gravity field, to the definition of protocols and standards in gravimetry as well as to the development and evaluation of innovative instrumentation (quantum gravimetry for instance). The strategic plan for the period 2023-2027 will maintain this objective, ensuring a long-term usability and sustainability of the highest-quality gravity data.

The BGI has its Central Bureau in Toulouse, France (GET/OMP) and operates with the support of various French agencies (CNES, CNRS/INSU, IGN, IRD, SHOM, BRGM, IFREMER), research labs and universities (Toulouse, Paris, Strasbourg, Montpellier, Nice, Brest, Le Mans). BGI also benefits from the close collaboration with agencies worldwide in charge of national gravity surveys and networks or regional data compilation: from Germany (BKG), Italy (POLIMI), Greece (AUTh), Czech Republic (VÜGTK), Denmark (DTU) and USA (NGA).

2 Mission, Objectives

The primary task of BGI is to improve the global knowledge of the Earth's gravity field through the collection, homogenization and validation of all available static gravity measurements (relative or absolute) and make this information available to a large variety of users for scientific applications. With this aim, BGI holds and maintains for IAG the four fundamental global databases of relative and absolute static gravity measurements and serves the scientific community. The current services provided by BGI include:

- Access to gravity data, reference stations, products, software and documentation.
- Archiving and validation of gravity dataset and products provided to BGI and attribution to data providers of a traceable international reference through a Digital Object Identifier (DOI).
- Realization and/or evaluation of global models as well as regional data compilations carried out for gravity or geoid studies.

BGI also actively contributes to the definition of protocols, practices and recommendations aimed at improving the gravity data acquisition and processing and the realization of gravity surveys and networks. BGI is more specifically involved in the following actions:

- Definition and establishment of the International Terrestrial Gravity Reference System & Frame (ITGRS/ITGRF), promoted through the IAG JWG 2.1.1.
- Evaluation of new sensors for measuring absolute gravity (cold-atom absolute gravity meters).
- Support the realization of national absolute gravity networks.

Finally, BGI also contributes with his collaborators to other research and development activities (software developments, research in geophysics and geodesy, etc.), as well as to educational activities in gravimetry (summer schools, tutorials, etc.).

3 Products and services

3.1 Global gravity databases

Land and marine gravity data

The relative gravity databases have been maintained and expanded since the early days of BGI. They have been extensively used for the definition of Earth gravity field models and for many applications in geodesy, satellite orbit computation, oceanography, geophysics, etc. They now contain over 12 million surface observations, providing precise, high-resolution information on the short wavelengths of the Earth's gravity field complementary to airborne and satellite gravity measurements. Since 2023, all data sets derived from old or recent surveys are granted a DOI assigned by the BGI.

Absolute gravity database (AGrav)

The absolute gravity database was set up in 2008 in cooperation between BGI and BKG (Bundesamt fur Kartographie und Geodasie, Germany) for collecting all available information on absolute gravity measurements acquired on Earth and for ensuring storage and long-term availability of data and processing details. The database can be accessed by a web-based interface which provides publicly available metadata as well as complete datasets for the community of users contributing to the archive. A simple web-based exchange format was selected to facilitate the upload of absolute gravity data to the database by the owner institutions. A new database and web interface developed jointly by BGI (Toulouse) and BKG (Leipzig), with the technical support from OMP Toulouse Data Service (Sedoo) was released in spring 2024 (Fig. 1). It offers new features and now provides the most comprehensive information on absolute gravity stations and measurements worldwide (raw or processed data, description of stations, instruments, involved institutions, contacts, etc.). The AGrav database will also serve as the reference data repository for the ITGRF. For correct data referencing, a DOI will be assigned to each instrument or network contributing to the AGrav database as well as to the ITGRF.

IGSN71 gravity reference stations

The gravity reference stations established and connected to the former IGSN71 and Potsdam reference systems have been previously collected and archived at BGI. For

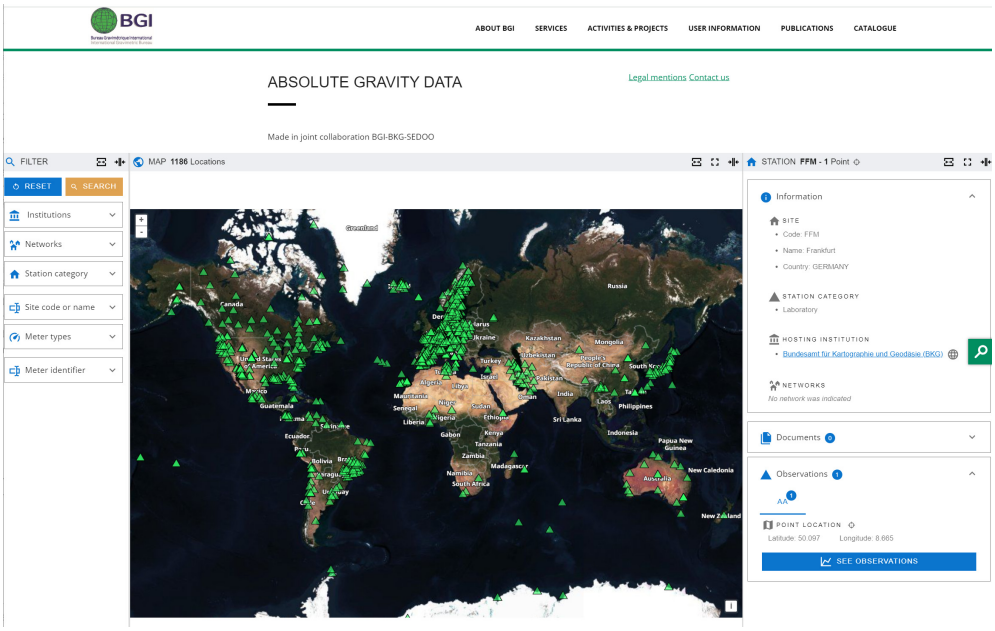

Fig. 1. The new Absolute Gravity database (AGrav) launched in 2024

decades, these stations have provided the only available information on absolute gravity value for tying local or regional relative gravity surveys (terrestrial, marine, airborne) in a global reference frame. Even if a significant number of reference stations should have disappeared with time, this original IGSN71 database remains accessible and is still used in some countries for calibration of relative surveys. This global gravity reference network will be advantageously replaced by the ITGRS/ITGRF based on the increasing network of actual absolute gravity measurements and made available from the AGrav database.

3.2 Global or regional gravity grids and models

BGI also contributes to the realization of derived gravity products aimed at supporting studies of the Earth gravity field at global or regional scales. The products mostly used by scientific users are the digital global grids from the World Gravity Map [6] which represent the first gravity anomalies (Bouguer, isostatic and surface free-air anomalies) computed in spherical geometry taking into account a realistic Earth model (Fig. 2). They include 1 minute resolution terrain corrections computed from the contribution of most surface masses (atmosphere, land, oceans, inland seas, lakes, ice caps and ice shelves). The World Gravity Map is also available as a set of 3 global maps realized for the Commission for the Geological Map of the World (CGMW). Other global or regional gravity models or data compilations computed at BGI or provided by other contributors may also be made available on the BGI website.

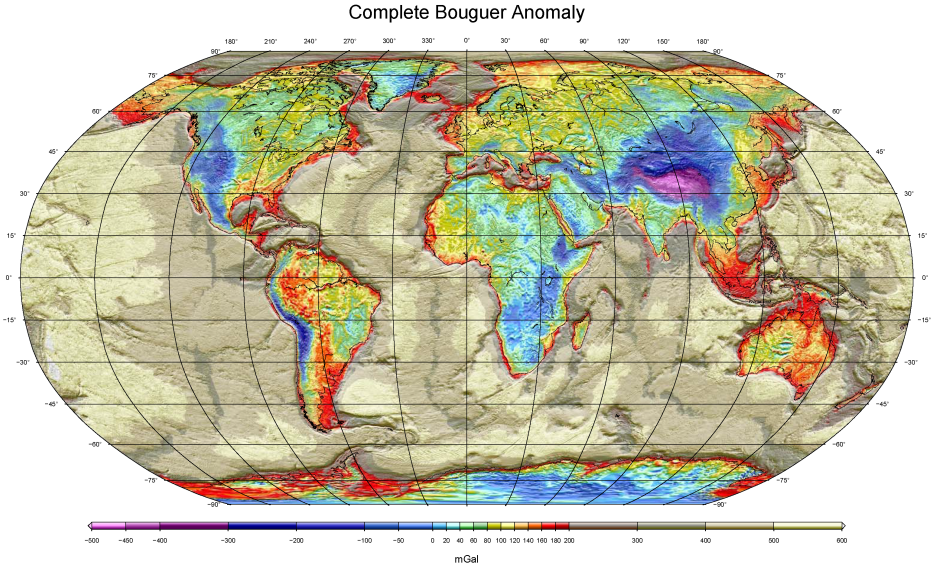

Fig. 2. Complete spherical Bouguer anomaly map of the word (source: BGI)

3.3 Software

BGI makes available on its website home-made tools and software developed for gravity data acquisition or validation such as CG6TOOL [7] for Scintrex gravity data processing or MGL_QuickView [8] for quick visualization of FG5 or A10 Micro-g LaCoste data acquisition results (project files).

3.4 Other services

- Online tools for prediction gravity at a given site.
- Documentation (historical bulletins 1950-2002, reports).
- Attribution of DOIs for relative and absolute gravity data set, products or software provided by contributors.

4 Program/Activities (2023-2027)

4.1 Database and services

The current activities at BGI are mostly dedicated to consolidate and validate the IAG global relative and absolute gravity databases and to develop pertinent and updated products and services for long-term sustainability and usability of gravity data for scientific purposes. The most significant actions released in 2023-2024 include:

- *A new BGI website* that provides services and information to both users and contributors. A catalogue of products freely distributed has been added.
- *The re-launch of the Absolute gravity database (AGrav)* with a new web interface and functionalities. AGrav is now accessible on the BGI website (https://bgi.obs-mip.fr) as well as from BKG (https://agrav.bkg.bund.de). Further developments are in progress to facilitate its maintenance and update (edition of metadata, upload of new dataset, check of data consistency, etc.) and its use (selective display of observations from a given network/institution/ instrument, plot of absolute gravity times series for a given station, etc.). The database will be updated with new contributions from corner-cube or quantum gravity instruments and the link to the development of the ITGRF will be strengthened.
- *The assignment of a DOI* to gravity datasets, products and software provided and archived at BGI. DOI are for instance already assigned to gravity datasets (either from recent or old gravity surveys) or to other products such as global or regional grids and models, data compilations, software, etc. For easier referencing, DOI landing pages have been developed. This will be extended soon to the AGrav database, with the assignment of DOIs to the absolute gravity instruments and networks from the contributing institutions.

4.2 Collection and validation of gravity data

BGI currently archives and validates new incoming gravity datasets. Data, products or software available at BGI are mostly dedicated to support scientific and academic activities. The contribution of countries, agencies and scientists involved in gravity data acquisition (relative or absolute measurements from field, marine or airborne surveys) is essential for improving the global coverage and accuracy of the Earth gravity field and for contributing to the determination of the new ITGRF. The archiving of new data sets also enables BGI to better validate the gravity observations in a global reference frame and restore them in standard and unified formats useful for the scientific end users. National agencies worldwide involved in the acquisition or compilation of gravity measurements and who wish to contribute to the updating of the IAG and ITGRF global gravity databases for a given country or region and to reference their works are invited to contact BGI.

4.3 Support to IAG/GGOS activities

The BGI contributes within IAG and GGOS to several Commissions, Working Groups and Projects aimed at improving:

- the global knowledge and accuracy of the Earth gravity;
- the definition and realization of gravity standards and networks;
- the development and evaluation of new gravity sensors (quantum gravimetry).

4.4 Development of the ITGRF

For the next 4 years, BGI will be strongly involved along with BKG in the development of the ITGRF. This initiative, launched in 2015, is being led by the IAG JWG

2.1.1, with support from the IAG Services BGI, IGETS and IGFS [9, 10]. It aims to provide a long-term global gravimetric reference based on absolute and traceable gravimetric measurements such as those provided by state-of-the-art absolute gravimeters (corner-cube or cold-atom). The proposed definition of ITGRS/ITGRF has given rise to several IAG resolutions since 2019 and will replace the obsolete International Gravity Standardization Net 1971 (IGSN71) developed in the 70's. It includes:

- *A primary global network of gravity reference stations* that will provide accurate, long-term absolute monitoring of the gravity field at selected stations where gravity can be continuously monitored at the µGal level (10^{-8} m s^{-2}). This network, possibly combined with other geodetic techniques, will contribute to the IAG/GGOS geodetic base site infrastructure. The target accuracy for this reference network, based on high-precision measurements, is of the order of a few µGal.
- *A secondary global network of gravity sites* determined from field or laboratory absolute gravity measurements, which will provide reference values for relative terrestrial, shipborne or airborne surveys, or for calibrating relative instruments. The target accuracy for this secondary network is of the order of a few to a few tens of µGal. The main contribution to this global network comes from the worldwide agencies responsible for national geodetic infrastructures.

4.5 New technologies of gravity measurements: Quantum gravimetry

BGI and its associated teams are involved in the evaluation of new gravity sensors such as those based on cold-atom technologies. In France, they have accompanied within the last few years the development and the evaluation of the first commercial Absolute Quantum Gravimeter (AQG) designed by MuQuans company, now eXail (Menoret et al., 2018) and of the first hybrid absolute gravimeter (including accelerometers and cold-atom sensor) designed by ONERA (France) for moving shipborne or airborne platform [11, 12]. They are also involved through the LNE lab in metrological developments in quantum gravimetry and in national and international inter-comparisons of absolute gravity meters (Fig. 3). These activities directly contribute to the IAG QuGe Project and to its WG Q.1 "Quantum gravimetry in space and ground".

4.6 Gravity compilations and studies

BGI will continue its activities related to regional gravity compilations. It has recently supported the realization of the Pan-Alpine gravity database [13] and a compilation on Vietnam and surrounding areas [14–16]. It also leads with the gravity group from POLIMI (Italy) the GeoMed2 project aiming at the realization of a high-resolution gravity and geoid model of the Mediterranean Sea. Gravity products derived from these studies are made publicly available from the BGI website.

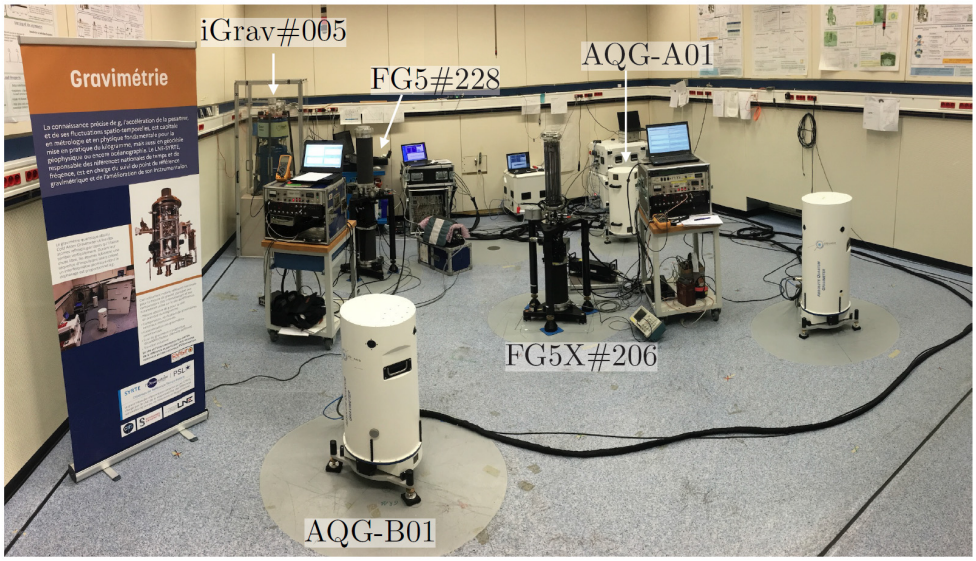

Fig. 3. Inter-comparison of quantum gravimeters at LNE facilities (source: S. Merlet)

4.7 Gravity surveys and networks

BGI associated teams also support the realization of gravity surveys and networks in the frame of national or international research projects with national agencies on the French territory as well as on other continents.

5 Structure

The BGI Central Bureau (management, secretariat and technical staff) is located in Toulouse, France, in the premises of the Observatoire Midi-Pyrénées (OMP) and Geosciences Environnement Toulouse (GET) research unit. BGI is supported by French agencies and universities, each of which has a representative member in the BGI Advisory Board (see list of experts below).

- Centre National d'Etudes Spatiales (CNES)
- Bureau de Recherches Géologiques et Minières (BRGM)
- Centre National de la Recherche Scientifique (CNRS)
- Institut National de l'Information Géographique et Forestière (IGN)
- Institut de Recherche pour le Développement (IRD)
- Service Hydrographique et Océanographique de la Marine (SHOM)
- Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)
- Institut de Physique du Globe de Paris (IPGP)
- Ecole et Observatoire des Sciences de la Terre (EOST)
- Ecole Supérieure des Géomètres et Topographes (ESGT)
- Université de Toulouse (GET/OMP)

- Université de Montpellier (Géosciences Montpellier)
- Université de Nice Sophia-Antipolis (GeoAzur)
- Université de Brest (Géosciences Océan)

Then, several French research units are involved in essential tasks carried out at BGI for the compilation, validation, analysis of gravity data, for the data acquisition (realization of gravity surveys or networks) as well as for the improvement of terrestrial gravity instrumentation and metrology (including quantum gravimetry).

Central Bureau (France)

- S. Bonvalot (GET/OMP, Toulouse); Director
- L. Seoane (GET/OMP, Toulouse); Deputy Director
- G. Balmino (GET/OMP, Toulouse)
- A. Briais (GET/OMP, Toulouse; GeoOcean/IEUM, Brest)
- S. Bruinsma (GET/OMP, Toulouse)
- G. Gabalda (GET/OMP, Toulouse)
- F. Reinquin (GET/OMP, Toulouse)

Advisory Board

Permanent correspondents (France)

- S. Merlet (LNE/SYRTE, Paris)
- A. Memin (GeoAzur, Nice)
- G. Pajot-Metivier (IPG, Paris)
- T. Gattacceca (IGN, St Mandé)
- R. Degoy (IGN, St Mandé)
- D. Rouxel (SHOM, Brest)
- C. Salaün (SHOM, Brest)
- M. Maia (GeoOcean/IUEM, Brest)
- G. Martelet (BRGM, Orléans)
- A. Peyrefitte (BRGM, Orléans)
- J.-P. Boy (EOST, Strasbourg)
- S. Rosat (EOST, Strasbourg)
- J.-D. Bernard (EOST, Strasbourg)
- N. Le Moigne (GM, Montpellier)
- J. Verdun (ESGT, Le Mans)

Permanent correspondents (other countries)

- H. Wziontek (BKG, Germany)
- V. Pálinkáš (VUGTK, Czech Republic)
- R. Barzaghi (POLIMI, Italy)
- G. Vergos (AUTh, Greece)
- R. Forsberg (DTU, Denmark)

IAG Representative

- U. Marti (FOT, Switzerland)

IGFS Representative

- R. Barzaghi (POLIMI, Italy)

6 Point of contact

Sylvain Bonvalot, Director
Lucia Seoane, Deputy Director
Bureau Gravimétrique International
Observatoire Midi-Pyrénées
14, Avenue Edouard Belin
31401 Toulouse Cedex 9, France
Phone: 33-5 61 33 29 80 / 33-5 61 33 47 04
E-mail:bgi@cnes.fr

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