

BUREAU GRAVIMÉTRIQUE INTERNATIONAL



Project 2007-2011

Presented by

BRGM Bureau de Recherches Géologiques et Minières



CNES Centre National d'Etudes Spatiales



CNRS/INSU Centre National de Recherche Scientifique
Institut National des Sciences de l'Univers



EOST Ecole et Observatoire des Sciences de la Terre



ESGT Ecole Supérieure des Géomètres et Topographes



UM2/GM Université Montpellier 2 / Geosciences Montpellier



IGN Institut Géographique National



IPGP Institut de Physique du Globe de Paris



IRD Institut de Recherche pour le Développement



SHOM Service Hydrographique et Océanographique de la Marine



Foreword

This proposal is submitted to the International Gravity Commission (IGC) of the International Association of Geodesy (IAG) at the 24th IUGG (International Union of Geodesy and Geophysics) General Assembly (July 2-13, 2007), Perugia, Italy. It is aimed at presenting the new project of BGI activities in France for the next four years.

The proposal is structured in three sections presenting (Section 1) the BGI in the international and national contexts (history, status, objectives and tasks, main achievements), (Section 2) the new challenges and the proposed actions (including a brief description of the recent activities at BGI in order to shed light on how the continuity of the present BGI services will be ensured) and (Section 3) the proposed operational plans to continue BGI activities, hopefully with some improvement and also enhancement with respect to gravity interests and recent advances in the area of gravimetry.

The ten supporting French organizations which planned contributions are presented in section 3. They have agreed that if and when the present proposal is accepted, a covenant between them will be established and will describe in detail and guarantee their respective inputs to the hosting and running of BGI over four year renewable periods.

A synthetic report (Annex A) summarizes the main activities and major achievements of BGI for period 2003-2007. The C.V. of the proposed new Director is given in Annex B.

Introduction

Over the last 50 years, BGI has played a fundamental role in the worldwide compilation and validation of gravity data and their distribution to the international scientific community. The BGI database, which now contains over 12 millions of observations compiled and computerized from land, marine and airborne gravity measurements, has been extensively used for the definition of earth gravity field models and for many applications in geodesy, satellite orbit computation, oceanography, geophysics, etc. In addition, BGI developed other additional services in the area of gravimetry such as validation and valorization of gravity or geoid data, bibliography database, online access to reference gravity stations, provision of tutorials and educational materials, expertise, etc.

Within the last decade, the measuring techniques in gravimetry have been significantly improved, providing new advances in the determination of the earth gravity field and its variations at any temporal and spatial scale. These improvements concern not only ground measurements but also airborne, seaborne and sea bottom measurements which are now complemented by a new type of satellite gravity data. New geodetic and gravity standards and reference systems are defined by geodesists and geophysicists. These evolutions lead to an increasing interest of the Earth sciences community in gravity data for a wide variety of applications (geodesy, physics of the earth, hydrology, oceanography, glaciology, geodynamics, tectonics, seismology, volcanology, earth tide studies, etc.). Consequences of these evolutions on BGI database and activities are expected.

In terrestrial gravimetry, three main inputs can explain the higher quality of the newly acquired gravity observations. (i) The development of new generations of gravity sensors (absolute and relative gravity meters, gradiometers...) and their consequences on accurate determinations of the earth gravity field in most environmental conditions (on shore, off shore and airborne surveys), on the definition of repeated or permanent monitoring networks, etc. (ii) The use of the satellite positioning techniques (GNSS) in land and marine gravity surveys providing more reliable gravity data at a worldwide scale and enhancing co-location of gravity and geodetic observables. (iii) The availability of precise global topography (SRTM for instance) and bathymetry models that contributes to map precisely the variations and anomalies of the earth gravity field.

In the same time, the first gravity-dedicated satellite missions CHAMP¹ and GRACE² launched in 2000 and 2002 respectively, provided a new class of information on the static gravity field and on its temporal variations. The imaging of mass transfer at global and regional scales within the superficial layers of the earth can be now retrieved from space. The future GOCE³ mission (to be launched in early 2008) will also provide the first mapping of the earth gravity field from global to local scales with unprecedented accuracy. These satellite data are defining new standards in gravity field modeling in global and regional scales. Nevertheless, instead of replacing the ground based gravity measurements, these new satellite measurements enhanced their complementarities with terrestrial data. The combination of these techniques thus provides to the Earth science community a continuum of gravity information over the whole spectrum of frequency with strong overlaps between space, ground, sea and airborne observations that need to be calibrated and combined with each others. This enhances the role of global database centers, such as BGI, in archiving the newly available terrestrial or satellite observations and providing updated and validated information to the Earth science community.

In this context we propose to maintain and to improve the BGI services aimed to compile, validate and redistribute gravity data and related information (reference base stations, bibliography database, etc.). Tasks which were not well accomplished, such as the systematic collection and archiving of absolute measurements will be realized. New orientations taking into account the recent developments in database management will be proposed to ease the data accessibility from the BGI database (open access and direct download of public data) and to support its interaction with other existing gravity related databases. As successfully demonstrated in the past, we also think that a contribution of BGI to educational and research activities, valorizing its activities and its global data base, contributes to improve the efficiency and the quality of the services. To achieve these objectives an updated organization of BGI strengthened by its supporting national and international organizations is proposed.

¹ CHAMP: high-low satellite-to-satellite tracking system using GPS; accelerometer for measuring non-gravitational forces; launch 07-2000; mission duration 5 years.

² GRACE: low-low satellite-to-satellite tracking system using microwaves; GPS on-board receiver; Accelerometers for measuring non-gravitational forces on both satellites; launch 03-2002; mission duration 5 years.

³ GOCE: satellite gradiometry mission; GPS/GLONASS receiver on-board; drag forces control by common mode accelerometer measurements; launch late 2007; mission duration 20 months.

1. CONTEXT

The present proposal is very dependent on the history of BGI and on its present functioning. It is based on the experience gained at BGI over the last decades and on the long term partnership between BGI and its supporting international and national organizations. Detailed reports from Balmino (1998) and Barriot (2004), the previous Directors of BGI, present the terms and references, the activities and evolution of BGI between 1979 and 2004. A brief presentation from these reports is given hereafter to enhance the present-day role of BGI in the international and national contexts.

1.1. BGI history: a short summary

The Bureau Gravimétrique International (BGI) has been created in 1951 by the International Association of Geodesy (IAG), one of the seven associations of which IUGG (International Union in Geophysics and Geodesy) is composed. The initial task of BGI was to collect, on a world-wide basis, all gravity measurements to generate a global digital database of gravity data for any public or private user. The technological and scientific evolutions which occurred over the last 50 years in the area of gravimetry (improvements in field, airborne and seaborne gravity meters, development of absolute and superconducting gravity meters, birth of spatial geodesy, etc.) provided significant increases of the number, diversity and accuracy of the gravity field observables. Following these evolutions, BGI contributed to provide original database and services for a wide international community concerned by the studies of the earth gravity field.

BGI, an international service

BGI is one of the offices of the Federation of Astronomical and Geophysical Services (FAGS) which operates under the auspices and in part thanks to the financial support of the International Council of Scientific Unions (ICSU) and the United Nations Educational Scientific and Cultural Organisation (UNESCO). It belongs to the International Association of Geodesy (IAG) of the International Union of Geodesy and Geophysics (IUGG). Since 2001, it is one of the “Centers” of the International Gravity Field Service (IGFS) which coordinates within the IAG, the activities of BGI, IGeS (International Geoid Service) and ICET (International Center for Earth Tides). The overall goal of IGFS is to coordinate the servicing of the geodetic and geophysical community with gravity field-related data, software and information.



IAG	IAGA	IAHS	IAMAS	IAPSO	IASPEI	IAVCEI
						

- International Association of Geodesy (IAG)
- International Association of Geomagnetism and Aeronomy (IAGA)
- International Association of Hydrological Sciences (IAHS)
- International Association of Meteorology and Atmospheric Sciences (IAMAS)
- International Association for the Physical Sciences of the Oceans (IAPSO)
- International Association of Seismology and Physics of the Earth's Interior (IASPEI)
- International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)

Associations of the IUGG (International Union of Geodesy and Geophysics)



IGFS (International Gravity Field Service)
 Director Rene Forsberg (Danish National Space Center)

International Gravimetric Bureau (**BGI**) - Director R. Biancale (CNES/GRGS Toulouse, France)
Collection, archiving and distribution of gravity data

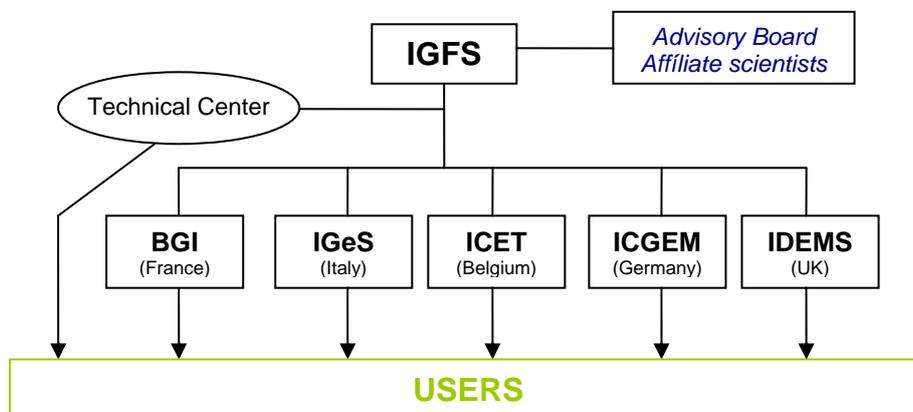
International Geoid Service (**IGeS**) – Director R. Barzaghi (POLIMI Milani, Italy)
Collection and distribution of geoid model, geoid schools

International Center for Earth Tides (**ICET**) – Director B. Ducarme (ORB Brussels, Belgium)
Collection and archiving of global earth tide data

International Center for Global Earth Models (**ICGEM**) – Director J. Kusche (GFZ Potsdam, Germany)
Distribution of satellite and surface spherical harmonic models

International DEM Service (**IDEMS**) – Director P. Berry (DeMontfort University, UK)
Global Digital Terrain Models

Technical Center of the IGFS – chief geodesist S. Kenyon (NGA S^t Louis, USA)
Advise on global models, geoid and gravity, supplementing other services



Structure of the IGFS (International Gravity Field Service)

BGI has had its offices located in France since its creation. Today, it is a permanent service of the Observatoire Midi-Pyrénées (OMP) in Toulouse, accredited by the Institut National des Sciences de l'Univers (INSU) and supported by ten French organizations involved in the activities of BGI.

BGI in France

BGI has been hosted by French organizations since its beginning in 1951. Under his first director, Reverend Father Lejay, it operated at the premises of the Society of Jesus in Paris, and its main objectives were at the instrumental and network settlement levels. The second director, P. Tardy, transferred the activities to IGN where he put the emphasis on archiving (cataloguing at that time) gravity data, and contributing to the establishment of a worldwide network - which was done under the leadership of IGC (this led to IGSN71); the Bulletin d'Information was regularly published. His successor, J.J. Levallois, recognized the growing importance of surface gravimetry in the global modeling of the Earth's gravity field as an invaluable complement to satellite data, also in physical geodesy for the determination of the geoid; his impulse was also determinant in starting the digitization of the gravity measurements in 1976 - with the help of BRGM, which resulted in the first BGI computerized archives (on magnetic tapes) ; at that time the service had been moved to and supported by IGP where gravity data were also used in studies of regional geophysical nature. In 1979, the Groupe de Recherche de Géodésie Spatiale (GRGS), a French federation of several teams working in the area of satellite geodesy, made a proposal to emphasize within BGI the synergy between satellite and surface gravity observations. This resulted, after the 17th General Assembly of IUGG (Canberra, Australia) at which this proposal was accepted, in the transfer of leadership to GRGS with the major support of BRGM, CNES and IGN (plus, a few years later, of INSU - a body of the French National Scientific Foundation: CNRS), and soon after to moving BGI to Toulouse in the premises of the technical Space Center of CNES. Since 1979, BGI has been housed in the Observatoire Midi-Pyrénées (OMP) for convenience and has been directed by G. Balmino (1979-1998) then by J-P. Barriot (1998-2007).

Since 1998, BGI has been supported by 10 French Organizations (see section 3) whose contributions to BGI over four year renewable periods are defined by a covenant.

1.2. BGI today

Tasks and objectives

The main task of BGI, as defined in the “Geodesist Handbook, 2004” is to collect, on a world-wide basis, all existing gravity measurements and pertinent information about the gravity field of the Earth, to compile them and store them in a computerized data base in order to redistribute them on request to a large variety of users for scientific purposes.

The data and products consist in: gravimeter observations (mainly location - three coordinates, gravity value, corrections, anomalies,...), mean free-air gravity values, gravity maps, reference station descriptions, publications dealing with the Earth's gravity. BGI also has access through his host agencies to satellite altimetry derived geoid heights (from Geos 3, Seasat, Geosat, ERS-1, ERS-2, Topex/Poseidon, etc.) and more recently to satellite derived gravity data (CHAMP, GRACE and soon GOCE); spherical harmonic coefficients of current global geopotential models; mean topographic heights. These data are sometimes used internally for data validation and geophysical analysis.

The data collection activities were especially conducted in the framework of large regional projects aimed to densify the world data coverage. BGI has put emphasis on the validation of received measurements, so as to improve the quality of the delivered information.

The current users of BGI services are:

- Geodesists (modeling of the earth gravity field, global and local geoid models, definition of the ocean mean surface, etc.)
- Geophysicists and geologists from universities, research laboratories, mining and petroleum companies (solid earth, oceanography, oil and mineral resources, resources hydrology, natural hazards, etc.)
- Industrials (developments of systems for inertial navigation, aeronautic, etc.)
- Developers of measuring instruments (balances, etc.)
- School and Universities (teaching)
- Military organizations

Main achievements

BGI has operated in a favorable context with the support of several French organizations. Thanks to this, permanent offices, permanent staff, logistics, computer equipment and time and travel money were provided. Details accounts of the achievements carried out at BGI along the last decades are given in reports from Balmino (1998) and Barriot (2004).

The main activities consist of :

- data collection,
- data archiving (ORACLE based, on a mainframe),
- data validation (thanks to various software packages developed in house, some with the contribution of Working Groups of IGC and of IAG scientists); this implies much scientific activity (e.g. use of satellite altimetry derived geoid heights, prediction methods, use of DEM,...),
- data distribution on CD-Roms, and via a server,
- maintenance of archives (reference stations, maps, bibliography) and their upgrades,
- provision of general information (data base contents, description of base stations, algorithms - and sometimes software, etc...) via a dedicated server (<http://bgi.cnes.fr:8110/>)
- publication of the Newton's Bulletin (in collaboration with ICET) with information on scientific or technical results in gravity and geoid, on meetings,...
- publication of data catalogues, of National Reports,
- education : providing tutorials put on the BGI server, contributing to summer schools,
- services such as performing the (cross-) validation of some data sets at the request of users or/and data contributors, gridding data sets, computing reference gravity from a global spherical harmonics model, etc...

A synthetic report in **Annex A** summarizes the main activities and major achievements of BGI for period 2003-2007.

2. NEW CHALLENGES AND PROPOSED ACTIONS

As mentioned above, the recent evolutions in gravimetry and geodesy methods and the launch within this decade of three satellite missions dedicated to the recovery of the earth gravity field have a direct impact on the activities of datacenters such as BGI. New interactions are required with different communities involved in gravimetry as for instance: with end-users of gravity data or products; with institutions involved in data acquisition as well as in research and development or educational activities; with other datacenters collecting complementary (satellite, airborne or ground based) gravity and geodetic data at regional or global scales. Up to now, BGI has been very reactive to consolidate and to improve its tasks and services to better match with such emergent constraints and opportunities.

According with the terms and references of BGI, we propose some specific actions to be continued or initiated for the next four years. They concern (i) tasks of service for data collection, validation and redistribution (section 2.1), (ii) activities of diffusion of gravity related information [section 2.2], (iii) educational activities [section 2.3] and (iv) research and development activities [section 2.4].

The main orientations consist in the following:

- to consolidate the terrestrial gravity databases (relative and absolute),
- to ease the consultation and diffusion of gravity data and products for end-users,
- to provide adequate data and services for both geodesists and geophysicists,
- to strengthen the contribution of BGI through its supporting organizations in educational, research and development activities aimed to maintain a high level of competence and its reactivity to external solicitations.

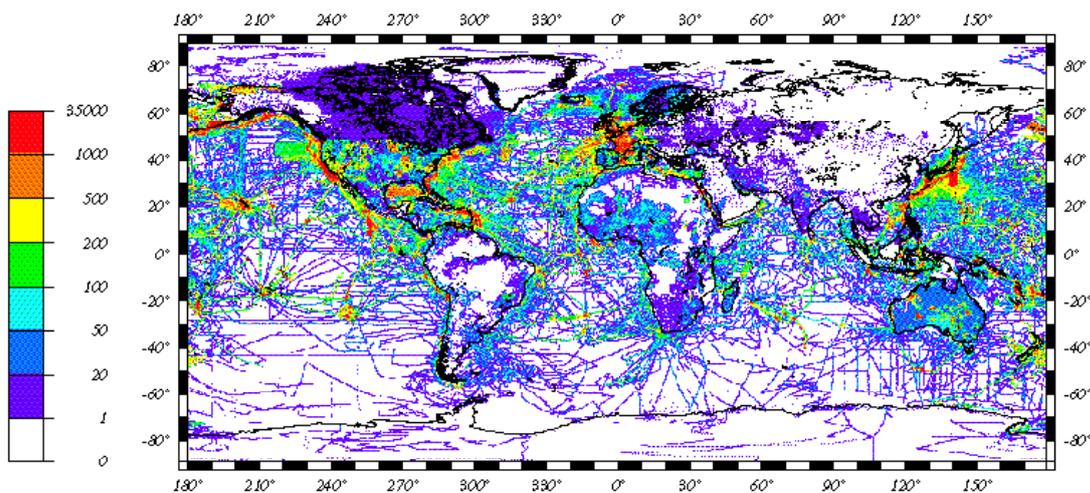
We briefly present hereafter the main actions we propose to be realized at BGI. Most of them have been initiated many years ago and are currently implemented by the BGI working group. Some others are new. The present-day status and the proposed new orientations are presented to enhance the way in which BGI could continue and improve its services and contribute to the synergy between national and international actors in gravimetry and geodesy.

2.1. Activities of service: data collection, validation and distribution

These activities remain the fundamental tasks of BGI. The main achievements consist in the relative gravity database, the database of reference gravity stations and the bibliography database. The Absolute gravity database and the airborne gravity database were insufficiently achieved due to the lack of man power in the past will be top prioritized in the next few years.

□ *“Relative gravity” database*

The BGI database contains today over 2,3 millions of land and 10,5 millions of marine gravity data. BGI has recently collected over 60000 data points from Belgium, Japan and Australia which are in process to be integrated into the database. This on-going effort of data collection of public or private data should be continued especially in regions where the BGI data coverage is poor with respect to the existing data (Russia, China, South America, etc.).



BGI relative on shore and off shore gravity database

As currently done, the new incoming datasets are validated using the standard procedures used, developed or updated at BGI. The conversion of the entire database into GRS80 system will be also achieved.

For many years, very few information was usually available on the reference datum systems for positioning, altitude or gravity. Thanks to the increasing use of GPS positioning in land or marine gravity campaigns, the recent surveys are better referenced in a global frame. The gravity stations coordinates and elevations are now determined with respect to given ellipsoid and datum. This contributes to enhance the reliability

between terrestrial gravity data and global satellite observations (gravity-topography-altimetry) which can be processed and merged with respect to homogeneous geodetic reference systems. When possible, BGI will provide additional information on the reference ellipsoid and datum system used for coordinates and elevations. Global SRTM topography or bathymetry models will be also used to detect systematic shifts of station elevations for a given dataset as a tool for data evaluation and validation.

The procedures for data distribution will be simplified in order to make them more efficient and interactive for the BGI users. Up to now, the public data that are freely available or restricted data (data available under authorization of the owner institution) are sent on request to users by BGI through FTP or CD-Rom. We propose to implement new automated procedures in order to facilitate direct download of public data from the BGI Website as currently done by other IAG data centers (earth tide data, IGS GPS, etc.). Obviously, this will concern public data freely available only and not other restricted or confidential data.

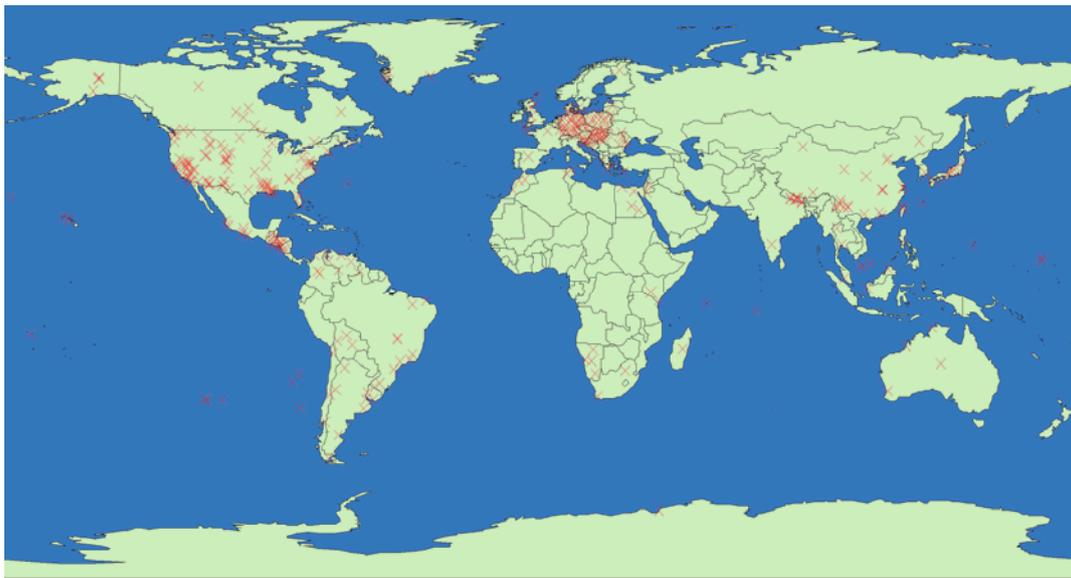
Another challenge is to make more visible and accessible the overall available information for a given request. Other national or international datacenters or agencies have developed gravity databases of public, non-public or commercial data. Among these existing databases, complementary information (meta-data or numerical data) might be shared with the BGI database. An effort will be done to establish links or mirror sites between BGI database and other existing databases. In favorable cases, inter-connections and inter-operability functionalities between databases will be implemented in order to offer an overview of the existing information.

□ *“Absolute gravity” database*

The dramatic increase of absolute gravity measurements calls for a compilation of the existing absolute stations and to make accessible the related information to the scientific community. The constitution of a global Absolute Gravity database is recognized by the International Gravity Commission as one of the main tasks for BGI.

In the last few years, BGI has contributed to working groups within the IGC activities for the setting up of the International Absolute Gravity Base Network (IAGBN) and UEGN (Unified European Gravity Network). A standard format for archiving absolute

gravity measurements has been defined⁴. In the same time, the commercial software “Absolute Gravity Data Acquisition and Processing Software” (“g”) developed by Micro-g LaCoste (main manufacturer of absolute meters) became a standard within the absolute gravity community. The resulting data files derived from the absolute measurements can be used to share and exchange unified information (ASCII files containing the basic information related with the data acquisition and processing settings, binary files produced during data acquisition that can be post-processed with other settings).



Referenced absolute gravity measurements⁵

Both the defined AGMAF-03 format and the reference “g” software give a good support to consolidate a worldwide absolute gravity database. Several organizations belonging to the BGI working group (see section 3) will actively contribute in this task (data collection and archiving, database construction and management, definition of an ITRF-type coding number of stations, etc.). This will be one of the main objectives of BGI for the next years. Collaboration with BKG (Bundesamt für Kartographie und Geodäsie, Frankfurt) and NRC (National Resources Canada) which have also initiated prototypes of A-G data base is also proposed to make the database compatibles.

⁴ Barriot, J-P., Sarrailh, M., Liard, J., Boedecker, G. - “AGMAF-03: An archiving format for Absolute Gravity measurements” (G03/07P/D-062) presented at IUGG 2003, Sapporo, Japan.

⁵ The number of absolute gravity determinations has been recently boosted. Complementing the standard laboratory-type FG5 meter (Micro-g LaCoste), new generations of portable and thermo-stated meters are now available (i.e. A10 meter). They are now commonly used in large scale surveys for measuring absolute gravity in most field conditions with accuracies in order or better than 10 microGal.

□ ***“Airborne gravity” database***

The collection and diffusion of airborne gravity data in worldwide database is not as well developed as land or marine data whereas it is commonly used in mineral and oil exploration. Airborne gravimetry remains a powerful tool to produce accurate and homogeneous gravity data acquisition on inaccessible areas (mountains, volcanoes, tropical forests, deserts, islands, continental margins, coastal areas...). It has thus strong implications on the determination of the gravity field and geoid at regional and local scales providing information in intermediate wavelengths between ground and satellite measurements. An effort in the data collection and validation of new datasets at BGI is necessary to improve the knowledge of the earth gravity field (especially in continental margins or inaccessible areas).

□ ***“Reference gravity station” database***

The global database of reference gravity stations has been finalized is accessible through the BGI internet website. It contains more than 6000 reference stations for which the complete site information (coordinates, monography, scheme and photos) have been scanned. Tables of the corresponding gravity values (with their reference system) are also available. All the related information (monography and gravity values) can be directly downloaded. The consultation is done using interactive maps as for the relative gravity database. New reference gravity stations will be also provided through the absolute gravity database.

□ ***“Bibliography” database (publications, maps...)***

The BGI bibliography database has been initiated in 2003 with the aim to inventory and to diffuse on a worldwide base, old and recent references related to gravimetry.

The database was developed under a standard and unified system (« Alexandrie » software) used by many other documentation centers in order to ease the integration of data, the database maintenance and the exchange of information between datacenters. This activity has been considerably consolidated within the last few years at BGI. The database now contains about 12300 references, ~3000 maps and 9350 textual (plus thesaurus of more than 400 terms and 6000 authors). The database can be consulted and interrogated by any user through the BGI website. It is regularly updated with new references from scientific articles published in journals, proceedings of meetings, technical papers, national and international reports, etc.

This activity will be continued and implemented in collaboration with other IAG/IGFS datacenters (such as ICET) hosting bibliography databases in the field of gravimetry (links between ICET and BGI databases).

2.2. Activities of diffusion

Website

The internet website is the key interface between BGI and its users. New functionalities should be implemented in relation with the database management to perform direct downloads of data or products from the webpage and allow inter-operability between other sites hosting gravity-related databases. A new interface will be developed to add these new functionalities and present the whole BGI services and activities as presently done (<http://bgi.cnes.fr:8110>). An effort will be done to homogenize the BGI website (menus, graphic charts, etc...) with the other websites of centers belonging to the IAG/IGFS. Links between BGI and the FROG bureau (French resources for GOCE exploitation) hosted at the Institut de Physique du Globe de Paris will be proposed in order to display a unified and more complete information regarding the French resources in gravimetry.

Diffusion of the Newton's Bulletin

The Newton's Bulletin is published jointly by BGI and the International Geoid Service (IGeS) and contains papers about geoid estimation and gravity. This bulletin was born in 2003 from the merging of the BGI and IGeS bulletins and has one issue per year (first number has been issued in Dec. 2003). It is composed of two sections presenting "reviewed papers" and "communications and news". The submitted papers undergo a peer review process. The 3 issues are available in electronic form (full text version in PDF format) on BGI and IGeS websites (<http://bgi.cnes.fr:8110>; <http://www.iges.polimi.it>). Paper issues and CD are also published for diffusion to libraries and archiving centers. The Newton's Bulletin will be continued improving the co-operation with IGeS and enlarging its Editorial Board. BGI will encourage the publication of research or technical papers as well as proceedings of meetings dedicated to terrestrial gravimetry.

Diffusion of public computer programs and software in gravimetry

The diffusion of computer software developed (and in use) at BGI for the validation of land and marine gravity data has been initiated few years ago. As for other IAG

services, it is recommended to maintain such activity that contributes to homogenize and standardize the validation and processing tasks in gravimetry. With this aim, BGI with its supporting organizations will intensify the compilation and diffusion of computer softwares related to the validation, processing and analysis of gravity data. Links to other databases or research centers compiling such computer programs will be done.

□ *Diffusion of gravity related information and products*

We propose to continue through the BGI website the diffusion of gravity database derived products such as geoid models, global or regional anomaly maps, etc. In addition, the diffusion of any product or information interesting the gravity community and users of BGI services is highly recommended (ex: procedures and results of data evaluation and validation, monthly GRACE solutions produced by GRGS, proceedings of gravity related meetings and workshop, national reports, etc.).

2.3. Contribution to educational activities

□ *Summer Schools and workshops*

BGI has been very active within these last few years in contributing to educational activities. Three Summer Schools, organized in the framework of IAG by ICET (International Center for Earth Tides) and IGeS (International Geoid Service) an BGI, were successfully realized in February 2000 (Malaysia)⁶, September 2002 (Belgium)⁷ and October 2005 (Canaria)⁸. The general purpose of these summer schools is to transfer theoretical and practical expertise in gravimetry towards graduate students, young scientists or employees of national agencies and services or industry staff. The February 2000 summer course was aimed to prepare the participants to use and to compute gravimetric geoids for the many scientific and technical applications we are met with in geodesy, primarily in transforming ellipsoidal (GPS) heights into orthometric heights. The two others were aimed to the training in gravimetric techniques of people involved in gravity and microgravity surveys with applications to

⁶ "Geoid schools", Johor Bahru, Malaysia, Feb. 2000

[jointly organized by BGI, IGeS in cooperation with the Department of Survey and Mapping Malaysia].

⁷ "Terrestrial Gravity Data Acquisition Techniques", Louvain-la-Neuve, Belgium, September 4-11, 2002

[jointly organized by BGI/ICET in cooperation with the Catholic University of Louvain].

⁸ "Microgravimetry methods: static and dynamics aspects", Lanzarote (Canaria), October 23-28, 2005

[jointly organized by BGI/ICET in cooperation with the Institute of Astronomy and Geodesy, Spain].

geodesy, geodynamics, geophysics, geology or civil engineering (operating of relative gravity meters, gravity data handling and processing, etc.).

The international audience (announcements published in EOS) and the number of participants (up to 45 participants from 22 countries for one summer school) confirmed the interest of the international community in such events. Interest of scientists from emergent and developing countries in techniques of acquisition, processing and interpretation of gravity data has been also enhanced.

We believe that BGI must contribute to this on-going effort of the International Association of Geodesy of spreading the technical culture for the determination and use of the geoid and gravity data. We propose that BGI co-organize one or two similar events in the next four years (proposed topics: relative or absolute gravimetry, validation of satellite and ground data, processing software, etc.). A project of summer school is planned in 2008 with support of ECGS and University of Luxembourg (program, participants and conditions to be defined). Partnerships and sponsors from national and international research and educational organizations will be searched to keep the effort for organizing low cost summer courses and workshops and then encouraging the participation of students and young researchers from emergent and developing countries. As done for the recent summer courses, BGI will also publish a CD-ROM (with ISBN reference number) containing all the teaching material. Possible subjects for further summer schools in which BGI could be involved: relative or absolute gravimetry schools (methods for acquisition, reduction or analysis of data, processing tools for earth tide corrections or network adjustment...), geoid schools, schools on combination, validation and exploitation of satellite (GRACE, GOCE) and terrestrial gravity datasets...

□ *Tutorials and educational materials*

A series of tutorials in gravimetry and geodesy (mostly in French at that time) are accessible on line on the BGI website. Internet statistics reveal that the request for such tutorials is high. We propose that BGI put emphasis to collect more tutorials or lecture notes in gravimetry and geodesy from research and educational institutions. Efforts to diffuse texts in English language will be done.

2.4. Contribution to Research & Development activities

Even if it is not its main task, BGI has conducted research activities mainly with its supporting research laboratories. Most of these activities valorize the current tasks of services and the global databases of BGI. They also contribute to maintain a good synergy between users, contributors and of databases.

In addition to the on-going projects in which BGI is already involved, new opportunities for BGI to increase his participation in processes for standardization, validation and valorization of gravity data and to strengthen his relationship with national and international organizations are also mentioned hereafter. The future activities will be mostly focused on federative projects that may have a significant impact for geophysicists and geodesists users of gravity data. They will be realized in strong collaboration with the supporting organizations of BGI and with other IAG datacenters.

□ *Contribution to the computation of regional geoids (EGG07, Ligure Sea)*

BGI has developed expertise in validation of gravity data, computation of geoid and gravity models and has participated as validation data center in various regional or global projects. The main projects in which BGI is currently involved are the realization of the new EGG07 European geoid (under leadership of Hanover University) and the development of methodologies for geoid computation at the sea-continent transition (case study on Ligure sea). It is also involved in the preparation of standard procedures for Global Gravity Field Validation in collaboration with IGeS and other national or international research groups.

□ *Contribution to evaluation and validation of satellite data (GRACE, GOCE)*

A contribution of BGI to the valuation and validation of the new satellite gravity data (GRACE and soon GOCE) might be also expected. In most scientific applications where high spatial or temporal resolution is required, it has been stated that such satellite data might be advantageously combined and validated by complementary ground information from terrestrial databases. BGI as one of the IAG/IGFS datacenter will contribute in preparing and providing relevant information from its databases (absolute or relative gravity measurements from ground, marine or airborne surveys, accurate time series from repeated or permanent monitoring networks, etc.). It might also contribute in the definition of standard methodologies aimed to combine ground

and satellite data as well as to discriminate geodynamics or environmental gravity signals. On-going projects in which BGI is likely to be involved for data validation concerns the European, African and South-American continents. Expected fallouts are for instance: (i) the imaging of the solid earth at various scales, (ii) the continental hydrology (investigation of time varying signals related with the African monsoon), (iii) the natural hazards (investigations of vertical motions, mass or density changes induced by earthquakes or volcanic activities in subduction zones), (iv) the mineral resources in Africa.

□ *Contribution to the definition of absolute gravity standards*

In the last few years, the BGI working group gained experience in absolute gravimetry. Three instruments owned by French research groups (two FG5 and one A10 meters) are now available and are currently used for the establishment of reference networks in France, Europe or elsewhere (South America, Antarctica, etc.). Such absolute gravity networks will contribute to define a new reference frame of terrestrial gravity data. The validation and standardization of absolute gravity measurements is thus essential. A contribution of BGI to the definition and diffusion of procedures for the acquisition, reduction or validation of these measurements is required (contribution to the establishment of reference networks, to the inter-comparisons campaigns of absolute and relative gravity meters, to the publication of their results, etc.).

3. OPERATIONAL PLANS

We propose that BGI continue operating with its supporting organizations, in a new framework aimed at improving its efficiency and the quality of its services. This new framework (BGI working group) consists in topical teams pertaining to various French organizations, each team contributing with its expertise and means to one or several areas of gravimetry, as mentioned in section 2. As written in the foreword, it is anticipated that a covenant be established in due time between the partners to precisely define the inputs of each one to BGI as mentioned below.

BGI will also strengthen its relationships with other IAG services in order to harmonize its contribution with other international services.

3.1. BGI working group

The distribution of the different tasks among the different partners, contributing to the BGI activities, is the following (in alphabetic order).

□ ***BRGM (Bureau de Recherches Géologiques et Minières)***

BRGM is an organization for research in geology and mineral prospecting (headquarters in Orléans, France). It has interests in the maintenance of networks and archiving of gravity measurements in France and overseas territories, and in the use of gravity for geological surveys and mineral prospecting.

BGRM will contribute to the modernization of BGI databases by implementing the required functionalities that will allow direct download of public data and interoperability facilities between other global gravity databases. It will also follow his participation in BGI research and teaching activities by bringing expertise on measurements and interpretation methods and will also contribute to the tutorials in gravimetry.

□ ***CNES (Centre National d'Etudes Spatiales)***

CNES is the French space agency, which has its technical center located in Toulouse, France. It has major interests in global models of the Earth's gravity field for various

applications (especially very accurate orbit determination of some satellites, e.g. as required by altimetry for oceanographic studies).

CNES has provided a major support to BGI since 1979 (database construction and maintenance, management of BGI activities, data compilation and validation, software, tutorials, etc.). It currently hosts and maintains the BGI gravity database and server. It will follow his support to BGI in the data collection, validation, archiving and distribution (thanks to the expertise acquired since 1979 and to the developed software and existing facilities), as well as in the teaching and research activities of BGI. It will continue bringing its support to BGI by providing: staff; computer facilities (for data validation, archiving and distribution, also for maintenance of the server).

□ *EOST (Ecole et Observatoire des Sciences de la Terre)*

EOST is a school and an institute in Earth sciences located in Strasbourg, France. It has interest in the study of temporal and spatial variations of the earth gravity field for the study of the physical processes at global, regional and local scales (applications to physics of the earth, geodynamics and hydrology). It is experienced in the measure of precise gravimetry (it operates two national instruments: a super-conducting gravimeter and an absolute gravimeter [FG5 #206]) and has contributed in the establishing of absolute gravity networks mostly in French territories, Antarctica and Europa. It has also interest in the use and combination of both terrestrial and satellite (CHAMP, GRACE, GOCE) gravity data.

EOST will contribute to BGI in the absolute gravity data collection and compilation and in the achievement of the absolute gravity database of BGI. It will also follow his participation in BGI research and teaching activities by bringing expertise on the following areas: measurements, validation and interpretation methods, tutorials and summer schools in absolute gravimetry.

□ *ESGT-CNAM (Ecole Supérieure des Géomètres et Topographes)*

ESGT-CNAM is an engineering school of surveying and mapping located in Le Mans, France. It has interest in the use of gravimetry and geodesy. It has developed expertise in airborne gravimetry in the areas of instrumentation (development of gravity sensors),

data processing and modeling. The ESGT-CNAM also seeks to further develop its competencies in geoid calculations.

ESGT-CNAM will follow his participation to BGI by bringing expertise in validation methods for gravimetric data based on geodesic information and in airborne gravity data acquisition and processing. It will participate, in the context of its educational role in applied geodesy and surveying, to research and teaching activities of BGI in the following areas: educative material including tutorials, summer schools.

□ ***GM - UM2 (« Geosciences Montpellier » - Université de Montpellier 2)***

GM-UM2 is the laboratory of Geosciences of the University Montpellier, France. It has interest in the study of temporal and spatial variations of the earth gravity field for the study of the physical processes at regional and local scales (applications to geodynamics, hydrology, earthquakes). It has a long experience with gravity campaigns, reduction techniques and interpretation methods and has developed an expertise in airborne gravimetry thanks to a close collaboration with the ETH (Zurich, CH). It has also gained experience in absolute gravimetry (it operates one of the national FG5 instruments) and contributes in the establishing of absolute gravity networks for his research programs.

GM-UM2 will contribute to BGI in the absolute gravity data collection. It will also follow his participation in BGI research and teaching activities by bringing expertise on the following areas: measurements, validation and interpretation methods, tutorials and summer schools in absolute gravimetry.

□ ***IGN (Institut Géographique National)***

IGN is the French national geographic and geodetic survey (Technical center in St Mandé, France). It has many interests in gravimetry for the establishment and the update of the gravity/geodetic reference frame and height systems, the computation of regional geoids and for the realization of regional gravity surveys. It has developed experience in relative and absolute gravity measurements and is co-owner with IRD and IPGP of the French portable absolute gravity meter [A10 #014]. Through his research laboratory in Geodesy (LAREG), it is involved in methodological and theoretical developments in the area of validation, interpretation and modeling of terrestrial and

satellite gravity data with applications to geodesy, physics of the Earth, geodynamics, etc.

IGN has provided a major support to BGI since 1979 (database construction and maintenance, data compilation and validation, data diffusion, etc.). IGN will contribute to the modernization of the BGI databases by implementing the required functionalities that will allow direct download of public data and interoperability facilities between other global gravity databases. It will participate to the Absolute gravity database by providing new observations and by defining a unified international coding of the absolute gravity sites. It will also follow his participation in BGI research and teaching activities by bringing expertise in the following areas: methods for gravity data validation and interpretation, tutorials in gravimetry.

□ ***CNRS/INSU (Institut National des Sciences de l'Univers)***

INSU is an organization within the French national scientific foundation (CNRS), dedicated to the sciences of the Universe. It supports scientific research laboratories or services. INSU supports BGI activities directly or through various research laboratories involved in gravimetry (mostly EOST, GM-UM2 and IPGP).

INSU has provided a major support to BGI since 1979 (database construction and maintenance, data compilation and validation, data diffusion, bibliography database, secretariat, etc.). It will follow his support to BGI through the recognition of his activities in France as one of his national observatory service (INSU label) and through the renewed contributions of his related research laboratories (see specific contributions of EOST, GM-UM2 and IPGP).

□ ***IPGP (Institut de Physique du Globe de Paris)***

IPGP is the largest institute of physics of the Earth in France (located in Paris). It has many interests in gravimetry for the study of physical processes at global, regional and local scales (studies of the temporal and spatial variations of the earth gravity field applications to physics of the earth, geodynamics, volcanoes, earthquakes, hydrology, etc.). It is experienced in the measure and exploitation of land, marine and sea-bottom gravimetry and in the use and combination of both terrestrial and satellite gravity data. IPGP owns several gravimeters (Scintrex and LaCoste & Romberg) and manages the

pool of INSU French relative gravity meters. It is also co-owner with IRD and IGN of the French portable absolute gravity meter [A10 #014].

IPGP will follow his long-term contribution to BGI activities by providing gravity observations from new campaigns established for his research purposes and expertise in interpretation methods for finer data validation, interpretation and modeling in geophysics. It will contribute to the development and the maintenance of software and educational material in gravimetry to be put on the BGI server. As hosting the French Bureau for the Coordination of Exploitation of GOCE data (Bureau FROG), it will also contribute to the validation of ground and space gravity.

□ ***IRD (Institut de Recherche pour le Développement)***

IRD is the French institute conducting cooperative research and educational programs with emergent and developing countries (ex ORSTOM). It has many interests in the use of terrestrial, marine or space gravity data for his research programs applied to solid earth, hydrology and oceanography. It has a long term experience in the measure and interpretation of gravimetry and microgravimetry data with applications to structural geology, geodynamics, volcanic and seismic hazards. IRD owns a pool of gravimeters (Scintrex) and is co-owner with IGN and IPGP of the French portable absolute gravity meter [A10 #014]. It also currently contributes to the establishment of absolute gravity reference networks (ex: South America).

IRD has contributed to BGI through his land and marine gravity databases (mostly in Africa – over 300000 data points - and South West Pacific). It will follow his contribution to BGI by collecting gravity data (relative and absolute) acquired or compiled in overseas countries for his research programs. IRD will contribute to the achievement of the absolute gravity database of BGI. It will also support BGI research and teaching activities by bringing expertise in the following areas: measurements, validation and interpretation methods, contribution to summer schools in gravimetry and diffusion of software or educational materials in emergent and developing countries.

□ ***SHOM (Service Hydrographique de la Marine)***

SHOM is the hydrographic and oceanographic service of the French navy (headquarters

in Brest). This is where the highest expertise in marine gravimetry (instruments, campaigns, data taking and reduction) lies in France.

SHOM has contributed to BGI through his marine gravity databases and through his expertise in validation of marine gravity data. It will provide part time personal to help BGI to emphasize the collection and validation of marine data. It will contribute to BGI in data collection, data validation, and educational activities.

3.2. BGI directing board / Coordinating Committee

The BGI directing board will be composed of the BGI director and a deputy-director. The management and the secretariat of BGI are located at the same place (OMP Toulouse) for efficiency. A Coordinating Committee, composed of the representative of each supporting organization, will be established in France to help the Directing board in his task and to harmonize the contribution of the different groups.

The Directing board will be in charge of the international relationships with the International Gravity Commission and its Working Groups, with other IAG and FAGS services. It will coordinate the fluxes of information between the kernel and the different teams and ensure good links between the teams themselves according to the decisions of the Coordinating Committee.

ANNEX A

Endorsement letters

To be included

ANNEX A

Synthetic report on BGI activities for period 2003-2007

BGI mainly focused on the following topics related with its databases:

- Relative gravity data collection and validation (increasing of 10 % of new data)
- Online availability of the bibliographic database, with entries added on a day to day basis.
- Online availability of reference gravity stations (scan of over 6000 descriptions and photos)
- Definition of an archiving format for absolute gravity data presented at the IUGG Sapporo meeting in 2003.

These actions were complemented by the continuation and development of other academic activities:

- Publication of the Newton's Bulletin, the Joint bulletin of the International Geoid Service and of the Bureau Gravimetric International.
- Organization of summer schools
- Participation in the new IGFS (International Gravity Field Service), the unified service of IAG for the determination of the gravity field and figure of the Earth, federating BGI, IGeS and ICET.
- Communications presenting BGI activities at international meetings

In addition, research and development activities were also conducted in relationship with research laboratories.

Persons currently working at BGI :

- J.P. BARRIOT, CNES Ing., 47 years (50 %), BGI Director
- R. BIANCALE, Ing. CNES, 54 years - Director by interim (Sept. 2006-July 2007)
- M. SARRAILH, CNES Ing., 55 years (50 %), à 50 %, data collection and processing.
- B. LANGELLIER, IGN Ing., 57 years, (100 %), database maintenance.
- S. PECQUERIE, CNRS Ing., 50 years (80 %), bibliography

- N. LESTIEU, CNRS Technician, 51 years, (20 %), secretariat
- T. FAYARD, CNES Ing., 44 years, (50 %), data acquisition
- M. ABBASI, 30 years, (100 % in 2003-2006), Ph.D. student, processing of airborne gravimetry.

1. Relative gravity database

Database archiving

The BGI database contains today over 2.3 millions of land and 10.5 millions of marine gravity data. New sets of relative gravity corresponding roughly to 700000 points are being included into the BGI data base. The table here below presents the status of the process in three categories: already processed, under examination and still to do.

Location	Number of points	Process status
Southern Arabia	2965	td
West Antarctic	297000	ue
US-San Bernardino	615	td
US-Portland	127	td
Philippines	1025	ap
Patagonia	29	td
US-North Willamette	4153	td
US-Nevada	80000	td
Nepal	152	ue
US-Minesota	57905	td
Philippines	482	ap
US-Lassen volcano	384	td
Reunion	1181	ap
France-Ile de Groix	250	ue
US-Haiward Fault	400	td
Greenland	32	td
South America Gotze	6152	ap
Spain Goyau	2047	ue
Brazil	8871	ap
US Albuquerque	5562	td
Australia	1117055	ue
Japan	90298	ue

ap : already processed, ue : under examination, td : to do.

Data requests

The number of data requests is the following:

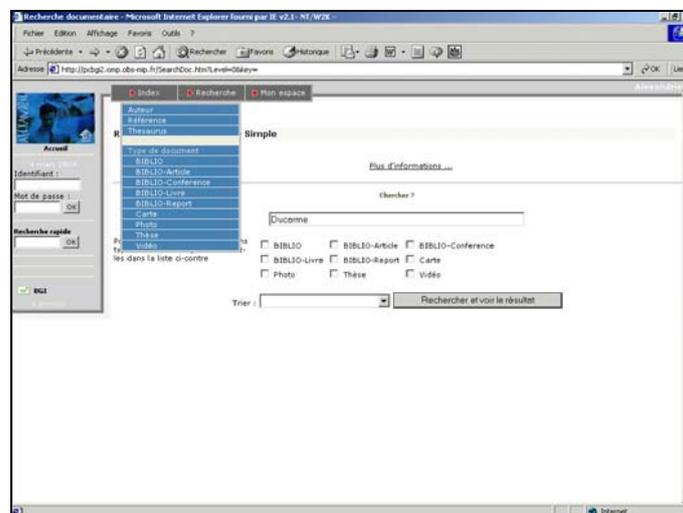
74 in 2003

94 in 2004

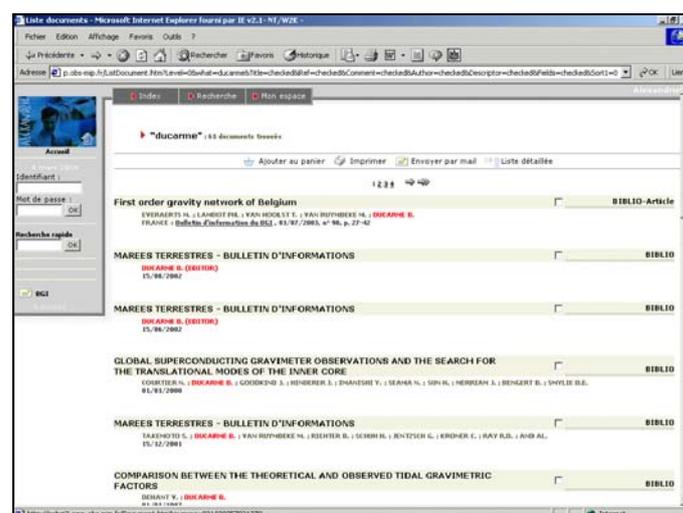
228 in 2005
123 in 2006
30 in 2007 (till June)

2. Bibliography database

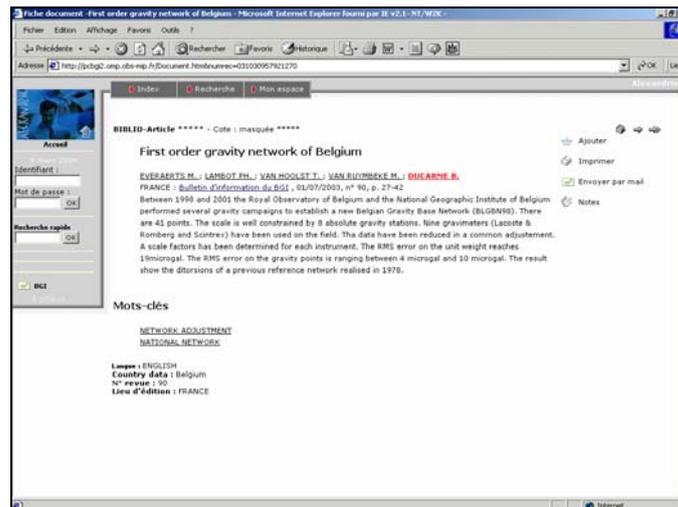
BGI maintains and develops its bibliography data base under the so called Alexandrie server. It contains 10300 paper references taken out from 150 publication or journal titles and includes 7232 authors and 429 thesaurus descriptors. Moreover 2950 map references and 200 digitalized maps are present. This base is on line at: <http://bgi.cnes.fr>. The total incurring cost was 7735 euros, a huge sum for BGI, which drained almost all our funds.



Example of request and with author name



Example of response



Example of response for a selected reference

3. Research and Development

Projects

- Participation to the new european geoid EGG07 under the leadership of Université de Hanovre, as validation data center
- In the framework of hydrogeological studies in the Garonne basin (France), BGI has contributed to microgravity monitoring of the subsurface water table. For this project, BGI carried out field surveys and realized hardware developments. It has developed an electronic data acquisition system aimed to convert analogical data from Lacoste gravimeter output into digital data stored in memory on board. The data are then unloaded on a PC computer through an USB port under Windows OS which makes data filtering easier and allows a better detection of instrumental problems.

Details of software developments

BGI has developed or renewed a few software packages for the preprocessing and the interpretation of gravity data, such as:

- A new software package for processing the airborne gravity data has been developed by Madjid Abassi in the framework of his PhD. This package is dedicated to the gravimeters of type Lacoste & Romberg air/sea model. On the contrary of classical methods used, this software processes aerogravimetric profiles in a global approach taking into account the intrinsic statistical

characteristics. The computation procedure of the new method includes the following steps :

- computation of the aircraft induced accelerations and estimation of their variance-covariance matrices;
 - removal procedure for subtracting the low frequency spectrum of the gravity disturbances;
 - transfer of the vertical accelerations and its variance-covariance matrix through the damper/platform transfer function;
 - construction of the a priori correlation matrix of the unknowns from the global geopotential models on the surveyed area;
 - computation of the estimated values of the unknowns and of their variance-covariance matrix.
- Inversion of gravity field in finite elements with a simulated annealing algorithm: this software delivers the underground density distribution from a set of surface gravity observations according to an input of geophysical constraints.
 - Sea gravity data adjustment package using a Singular Value Decomposition algorithm: this software detects and adjusts (by least squares method) crossovers between gravity profiles. It was used to calibrate marine data profiles in the Ligurian Sea.
 - A new versatile conversion tool for gravity data integration and validation, some software for gravity data preprocessing (drift removal...) and simulation as well.
 - Interpret: this interactive package allows the determination of the gravity anomalies of 2D and 2.5D structures. It is mainly dedicated to educational training, but can be used professionally to estimate the gravity effects of given structures.

4. Summer schools

After the first joint BGI/ICET Summer School on terrestrial gravity data acquisition techniques held in Louvain-la-Neuve in 2002, BGI, associated with ICET and the Instituto de Astronomia y Geodesia (IAG), organised in October 2005 in Lanzarote, Canaries, a new Summer School on micro-gravimetric methods. The school program

included courses about the instruments, the static and dynamic aspects and practical sessions. A total of 16 students and 15 teachers participated to the School.

5. Communications and publications of BGI for period 2002-2005

- J.P. Barriot, Least Squares Processes and Imaging, XVIII^{ème} Curso de Volcanologia, Lanzarote Island, June 14th, 2005.
- M. Abbasi and J.P. Barriot, Différentiation de séries chronologiques et estimation des matrices de covariance associées. Application en gravimétrie mobile, Poster, 2^{ème} Congrès National de Mathématiques Appliquées et Industrielles, Evian, France 23-27 Mai 2005.
- M. Abbasi, J.P. Barriot, J. Verdun et H. Duquenne : Gravimétrie aéroportée : une méthode alternative de calcul par inversion intégrale, Poster, Journées de Gravimétrie Spatiale, Paris, CNES, 11 Mai 2005.
- J.P. Barriot, M. Sarrailh, B. Langellier, S. Pecquerie and T. Fayard, The database of the International Gravimetric Bureau and its Services, Geo-Siberia Fair and Conference, Novosibirsk, Russia, April 25-29th, 2005.
- M. Abbasi and J.P. Barriot, Airplane induced accelerations in airborne gravimetry: computation and accuracy estimation, Geophysical Research Abstracts, Vol. 7, 00168, 2005 SRef-ID: 1607-7962/gra/EGU05-A-00168, Vienna, April 24-30th, 2005.
- M. Abbasi, J.P. Barriot, J. Verdun and H. Duquenne, Airborne Lacoste-Romberg gravimetry; an alternative computation approach, Geophysical Research Abstracts, Vol. 7, 00167, 2005 SRef-ID: 1607-7962/gra/EGU05-A-00167, Vienna, April 24-30th, 2005.
- M. Abbasi, J.P. Barriot, J. Verdun and H. Duquenne, Data snooping, correction and reduction of the airborne gravimetry data acquired by a LaCoste-Romberg air/sea gravimeter, Poster, Ateliers d'Expérimentation et d'Instrumentation, Toulouse, France, 8 et 9 Février 2005.
- T. Fayard, M. Sarrailh, J.P. Barriot et B. Massat, Mesures Micro-Gravimétriques en Hydrologie, Poster, Ateliers d'Expérimentation et d'Instrumentation, Toulouse, France, 8 et 9 Février 2005.
- J.P. Barriot, M. Sarrailh, B. Langellier, S. Pecquerie and T. Fayard, Present days Activities at BGI, in 2005 Geoid School « The determination and use of the Geoid », Budapest, Hungary. Jan. 31-Feb. 04, 2005.
- J. Chenal and J.P. Barriot, A simple anisotropic model of the covariance function of the terrestrial gravity field over coastal areas, Newton's Bulletin, Vol 2., Dec. 2004.
- H. Denker, J.P. Barriot, R. Barzahi, R. Forsberg, J. Ihde, A. Kenyeres, U. Marti, I.N. Tziavos, Status of the European Gravity and Geoid Project EGGP., Proceedings of the Gravity, Geoid and Space Missions IAG International Symposium, Porto, Poster, Portugal, Aug. 30 –Sept. 3, 2004, submitted to the Proceedings.
- J.P. Barriot, A new derivation of the least-squares collocation formula, Abstracts Journal Series : Geodesy and Aerial Survey, n° 2, 2004.
- J.P. Barriot, S.Pecquerie, Services d'Observation : du nouveau. Inf'OMP, N° 20, 1er trimestre 2004.
- J.P. Barriot, M. Sarrailh, T. Fayard, Monitoring of the Garona river Table By MicroGravimetry: results of the 2003-2004 Campaign, Poster RSTGV-A-00243, Réunion des Sciences de la Terre – Joint Earth Sciences Meeting, Sept. 20-25 2004, Strasbourg, France.
- Abbasi M., Barriot J.P., Verdun J., Duquenne H, Data snooping, correction and reduction of the airborne gravimetry data acquired by a LaCoste-Romberg air/sea gravimeter, , Poster with CD Proceedings, Gravity, Geoid and Space Missions 2004, IAG International Symposium, Porto, Portugal, Poster, CD Proceedings, Aug. 30 –Sept. 3, 2004
- Barriot J.P., Sarrailh M., Pecquerie S., Langellier B., The gravimetric and bibliographic databases of the International Gravimetric Bureau, Gravity, Geoid and Space Missions 2004, IAG International Symposium, Porto, Portugal, Poster, CD Proceedings, Aug. 30 –Sept. 3, 2004.

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- M. Abbasi,, J.P. Barriot, J. Verdun and H. Duquenne, Investigation of the Systematic Errors Contaminating Airborne Gravimetry Data Acquired by a Lacoste-Romberg Air/sea Gravimeter, Geophysical Research Abstracts CD, Vol. 6, 00099, 2004, ISSN 1029-7006, EGU General Assembly 2004, Nice, France, 25_30 April 2004.
- J.P. Barriot, M. Sarrailh, Ajustement of Gravimetric Networks, Newton's Bulletin, n°1, Décembre 2003.
- J.P. Barriot, M. Sarrailh et T. Fayard, Surveillance gravimétrique de la variation de la nappe phréatique superficielle associée à la Garonne au niveau de Portet, Colloque d'ouverture du GDR G2, 12-14 Nov. 2003, Paris.
- J.P. Barriot, M. Sarrailh, T. Fayard and P. Pastor, Monitoring the Garona River water table by microgravimetry and GPS. Poster HW03/11A/D-002, Sapporo, UGGI General Assembly, July 2003.
- J.P. Barriot, M. Sarrailh, J. Liard, G Boedecker, AGMAF-03, an archiving format for absolute gravity measurements. Poster G03/07P/D-062, Sapporo, UGGI General Assembly, July 2003.
- L. Sliwa, J.P. Barriot. Establishment and Maintenance of a Gravity Network in the Carribean. Bulletin d'Information du Bureau Gravimétrique International. 91: Dec 2002
- M. Sarrailh, J.P. Barriot. Gravity data validation and outlier detection using L1 norm. Bulletin d'Information du Bureau Gravimétrique International. 91: Dec 2002
- JP Barriot and M. Sarrailh, J.L. Liard, G. Boedecker, Toward an unified format for the archiving of absolute gravity measurements at BGI. Instrumentation and Metrology in Gravimetry Workshop, Munsbach, Luxembourg. 28 Oct 2002
- J.P. Barriot. General theory of the gravity field. Lecture given at the joint BGI/ICET Summer Course, Louvain-La-Neuve, Belgium. 4 Sep 2002
- L. Sliwa, J.P. Barriot. Establishment and Maintenance of a Gravity Network in the Carribean. Third meeting of the International Gravity and Geoid Commission, Thessaloniki, Greece. 1(28), 26 Aug 2002
- M. Sarrailh, J.P. Barriot. Gravity data validation and outlier detection using L1 norm. Third Meeting of the International Gravity and Geoid Commission, Thessaloniki, Greece. 1(13): 10, 26 Aug 2002
- J.P. Barriot, B. Langellier, M. Sarrailh. Database management at the Bureau Gravimétrique International. Third Meeting of the International Gravity and Geoid Commission, Thessaloniki, Greece. 1(12): 9, 26 Aug 2002
- J.P. Barriot. A new derivation of the least-squares collocation formula. Bulletin d'Information du Bureau Gravimétrique International. 90: pp. 43-51, Jul 2002

ANNEX B

CV of the new proposed Director

Curriculum Vitae

Dr. Sylvain BONVALOT

Born November 11, 1961 - Paris, France (French nationality)

Geophysicist (permanent research investigator at IRD, France)

Academic degrees

- Thèse de Doctorat en Géophysique de l'Université P. et M. Curie (Paris 6), Juin 1990
« Mesures gravimétriques en Guinée et en Sierra-Leone. Modélisation structurale et étude du comportement mécanique de la lithosphère » (directed by P. Mechler)
- DEA en Géophysique de l'Université P. et M. Curie (Paris 6), Juin 1985
- 1^{er} et 2^{ème} cycles universitaires à l'Université P. et M. Curie (Paris 6), de 1979 à 1984

Professional positions

- Since 1991: Research investigator at IRD (ex-ORSTOM)
- 2002-2006: Associated research investigator at University of Chile
- 1995-2001: Associated research investigator at Institut de Physique du Globe de Paris
- 1986-1991: Ph-D student, voluntary nat. service, contracted young investigator at ORSTOM
- 1985: DEA student at Institut Français du Pétrole (Département de Géophysique marine)

Affectations

- Since 2007: University of Toulouse / Observatoire Midi-Pyrénées (LMTG, BGI)
- 2002-2006 : University of Chile (Fac. de Ciencias Físicas y Matemáticas, Dep. Geofísica)
- 1995-2001: Institut de Physique du Globe de Paris (Lab. de Gravimétrie et Géodynamique)
- 1988-2001: IRD Bondy France (Lab. de Géophysique)
- 1986-1988: ORSTOM Dakar, Senegal (Lab. de Géophysique)

Research interests

Gravimetry and satellite Geodesy applied to solid earth studies (geodynamics, volcanoes, earthquakes)

- Volcanology: Detection and interpretation of mass transfer and volcanic ground deformations using microgravity, GPS and InSAR interferometry; Structural modeling of active volcanoes using gravity
- Tectonics: Detection and interpretation of crustal vertical motions in seismic zones using Absolute Gravity and permanent GPS
- Structural geology : Gravity study of geological structures at regional scales (West Africa, Andes)
- Methodology: protocols of data acquisition and processing in relative and absolute gravimetry, GPS and INSAR interferometry for monitoring active volcanic and tectonic zones

*PI and Co-I of about 12 research projects in gravity and geodesy since 1990
with founding from national French (INSU, IRD) or Chilean (CONICYT) agencies
and from the European Space Agency (ESA Category 1 projects)*

Field experience in gravimetry-geodesy

Regional and local surveys (relative gravimetry, GPS)

- Africa (1986-1988). Realization of regional gravity and GPS surveys of 7 countries of West Africa (Sierra Leone, Guinea, Mali, Guinea Bissau, Ivory Coast, Benin) as responsible for gravity data acquisition and processing (collaboration with IGN France and DMA USA).
- Active volcanic and tectonic zones (1991-2007): Realization of local surveys for structural study (1) on active volcanoes in Central and South America, Reunion, Indonesia and (2) on active tectonic zones in the Andes (Chile, Argentina, Bolivia).

High precision networks (absolute and relative gravimetry, GPS, CGPS)

- Installation of microgravity monitoring networks (1991-2007) : (1) Active volcanoes in Ecuador (Cotopaxi, Pichincha), Chile (Lascar, Lastarria), Peru (Misti), Nicaragua (Masaya), Reunion (Piton de la Fournaise), Italy (Vulcano) ; (2) Active tectonic zones in the Andes (Chile, Argentina, Bolivia)
- Participation to Inter-comparison campaigns at BIPM (since 1994)
- Microgravity and CGPS monitoring of a natural gaz storage (1999-2001)
- First GPS measurement of the altitude of Mont Blanc (1986)

Marine and sea-bottom surveys

- Participation to 3 oceanographic cruises (Atlantic, Pacific): (1) gravity study of the African continental margins (1987) ; (2) sub-marine gravity survey in the mid-Atlantic ridge (Nautile) ; (3) gravity study of a submarine volcanic caldera in Vanuatu Islands.

Scientific committees

- Member of « Comité de coordination du Bureau Gravimétrique International (BGI) » (since 1998)
- Member of « Comité français de pilotage du gravimètre absolu national FG5 » (since 1996)
- Member of « Comité français de pilotage du gravimètre absolu national A10 » (since 2005)
- Member of the working group for « Acquisition d'un gravimètre absolu national » (1988-1996)
- Member of the working group for « Renouvellement du gravimètre marin du N.O. l'Atalante » (1996)
- Member of gravity group of « Comité National de l'Information Géographique » (1995-1998)
- Member of « Conseil Scientifique de l'IRD (ex-ORSTOM) » (since 2004)
- Member of « Commission Scientifique Géologie-Géophysique de l'ORSTOM » (1995-1999)
- Member of « Commission Scientifique Géologie-Géophysique de l'ORSTOM » (1992-1995)

Other

- Referee of scientific papers for ISI journals (EPSL, Pure & Applied Geophysics, Journ. of Volc. and Geoth. Res., Tectonophysics, Geophysical Research Letters,...) and for AGU monographies
- Referee of scientific projects for national programs (INSU-France; CONICYT-Chile; NSF-USA)
- Membership of American Geophysical Union (AGU) and European Geophysical Union (EGU)
- Representative of IRD in Chile - by interim (2002-2006)
- Responsible of « laboratoire de géophysique du centre IRD Bondy » (1994 à 1996)

Teaching

- Co-Director of 3 Doctorate thesis in gravimetry/geodesy at IPG Paris (D. Remy, 2005; A. Pavez, 2005) and at Université de Savoie (J-P. Metaxian, 1994)
- Co-Director of master and licence thesis in gravimetry/geodesy (IPGP, Univ. Paris 6, Univ. of Chile)
- Lectures in Gravity / Geodesy at the University of Chile (2002-2006)

Languages

- French (native) / English / Spanish

Publications

Articles in ISI Journals

- [23-2007] **Bonvalot, S.**, Remy, D., Deplus C., Diament, M., Gabalda, G. Insights on the March 1998 eruption at Piton de la Fournaise volcano (La Réunion) from microgravity monitoring. Submitted to *Journal of Geophysical Research*.
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