International Gravity Field Service - IGFS

http://igfs.topo.auth.gr/

Chairman: Riccardo Barzaghi (Italy)
Director of the Central Bureau: George Vergos (Greece)

The IGFS structure

The present day IGFS structure is summarized in the following chart

BGI (Bureau Gravimetrique International), Toulouse, France
ISG (International Service for the Geoid), Politecnico di Milano, Milano, Italy
IGETS (International Geodynamics and Earth Tides Service), EOST, Strasbourg, France
ICGEM (International Center for Global Earth Models), GFZ, Potsdam, Germany
IDEMS (International Digital Elevation Model Service), ESRI, Redlands, CA, USA
Auth (Aristotle University of Thessaloniki), Thessaloniki, Greece
NGA (National Geospatial-Intelligence Agency), USA

IGFS coordinates the activities of the Gravity Services (BGI, ISG, IGETS, ICGEM, IDEMS) via its Central Bureau at the Aristotle University of Thessaloniki (Greece), the Advisory Board and the Technical Centre at NGA (USA).

The members of the IGFS Advisory Board are:

- S. C. Kenyon (USA)
- J.-P. Barriot (French Polynesia)
- S. Bonvalot (France)
- F. Barthelmes (Germany)
- U. Marti (Switzerland)
- R. Pail (Germany)
- S. Bettadpur (USA)
- H. Denker (Germany)
- Y. Wang (USA)
- L. Sanchez (Germany/Columbia)
- L. Vitushkin (Russia)
- M. G. Sideris (Canada)
- J. Huang (Canada)
- A. Eicker (Germany)
Through this structure, the interaction between the Gravity Services proved to be effective and able to provide users with the required gravity products. Another important task of IGFS is to be an interface between the Gravity Services and GGOS. Particularly, in this respect, the IGFS actions have been performed in strict contact with the GGOS Bureau of Products and Standards, the Bureau of Network and Observations and GGOS Focus Area on “Unified Height Systems”. Finally, IGFS is cooperating with IAG Commissions and Inter-Commission Committee on Theory through Joint Working and Study Groups, namely:

- JSG 3.1: Intercomparison of Gravity and Height Changes (joint with Commissions 1, 2 and 3)
- JWG 0.1.2: Strategy for the Realization of the International Height Reference System (joint with GGOS, Commission 1, ICCT)
- JWG 2.1.1: Establishment of a global absolute gravity reference system (joint with Commission 2)
- JWG 2.2.1: Integration and validation of local geoid estimates (joint with Commission 2)

Overview

In the period 2016-2017, IGFS activities were mainly addressed on one side to improve the internal organization and, on the other side, to strengthen the connections with GGOS and IAG Commission 2. Parallel to that, standard activities have been also performed, i.e. actions related to: coordinate collection, validation, archiving and testing of gravity field related data; coordinate exchange of software of relevance for gravity field activities; coordinate courses on gravity field estimation; distribute information materials related to the earth's gravity field. Although most of these activities have been performed in a direct way by the related Gravity Services, they have been supervised and harmonized by IGFS.

The internal structure has been revised. A new Central Bureau has been established since, after IAG/IUGG in Prague, OGS decided to end this activity. The call for the IGFS CB was sent out at the beginning of 2016 and on April 1st, 2106 the new CB, hosted at the Aristotle University of Thessaloniki (Greece), started its activity. Furthermore, in 2016, the ICET Service evolved in the new International Geodynamics and Earth Tides Service (IGETS) aiming at extending and integrating the activities of the International Centre for Earth Tides (ICETS) and of the Global Geodynamics Project. Also, in 2016, the International Digital Elevation Model Service (IDEMS) was moved from De Montfort University (UK) to ESRI Company (USA) which is now in charge for distributing data and metadata on DEMs.

All this reorganization procedures were managed and carried out by IGFS in cooperation with its Advisory Board and in agreement with the IAG EC.

In the near future, a new service is going to be added to IGFS. This will be the International Combination Service for Time-variable Gravity Field Solutions (COST-G), the continuation within the framework of IGFS of the H2020 European Gravity Service for Improved Emergency Management project (EGSIEM). One of the main objectives of EGSIEM was to unify the knowledge of the GRACE community in order to come to a standardisation of gravity-derived products describing mass transport in the system Earth. The key role of this data is widely known in the geodetic community and it is thus of extreme importance to have this service under the IGFS umbrella.
As mentioned, external actions were mainly performed in connection with GGOS activities. IGFS representatives attended the GGOS Days Meetings held in Frankfurt, Germany (October 21st-23rd, 2015) and Cambridge, USA (October 24th-27th, 2016). IGFS representatives have also been involved in the GGOS Bureaus meetings held in San Francisco (during AGU 2015, 2016) and Vienna (during EGU 2016, 2017). Through these activities, a closer cooperation between the Gravity Filed Services and the Geometric Services of IAG was reached. Furthermore, standards on gravity metadata were developed (based on the GGOS Bureau of Products and Standards recommendations) and implemented in the new IGFS web page. IGFS actions in GGOS were also performed within the framework of the Focus Area on “Unified Height Systems”. In this respect, IGFS actively participated to the definition of the International Height Reference System/Frame (IHRS/IHRF).

Cooperation with IAG Commission 2 is based on the activities of several Joint Working and Study Groups that have been established at the last IAG/IUGG Assembly in Prague. Also, on September 19th-23rd, 2016, IGFS and Commission 2 co-organized the 1st Joint Commission 2 and IGFS Meeting in Thessaloniki, named “International Symposium on Gravity, Geoid and Height Systems 2016”. This conference series will be continued in the forthcoming future since Commission 2 and IGFS are planning to organize the second joint meeting on the first half of September 2018, in Copenhagen.

Finally, IGFS is managing the Geomed2 project, an ESA supported project, for the computation of the geoid and the DOT in the Mediterranean area. This project involves most of the Gravity Services related to IGFS.

The IGFS Central Bureau and the IGFS web page

With the International Gravity Field Service (IGFS) Central Bureau (CB) being hosted at the Department of Geodesy and Surveying (DGS) of the Aristotle University of Thessaloniki (AUTH) since April 2016, an effort was put forth in order to update its presence in the web and make the IGFS data and products more visible to the interested scientific and user community. To that respect, a first webpage has been created presenting mostly administrative information for IGFS and its services in order to guarantee its presence online.
Given the need to promote the work carried out by IGFS Services and Centers, a new updated webpage has been recently created focusing more on the data and products availability, so that interested users can acquire them directly from the available portals (see figures below). In the new webpage layout, the availability of gravity, geoid, GEM, DEM, SG and tide data through the IGFS services portal is more visible, while a news section has been created as well to direct to IGFS related conferences, updates, etc.

The recently updated IGFS webpage, online since October 2016

Finally, two mailing lists have been developed within IGFS CB:
igfs-products@lists.auth.gr: the scope of this list if to provide updated information on the new data and products that become available from the IGFS Services. New data and products such as GEMs, DEMs, gravity, geoid, SG, tide, etc. will be posted and shared to all list members. Subscription to the list is free. The list can be accessed at https://lists.auth.gr/sympa/info/igfs-products
igfs-standards@lists.auth.gr: the scope of this list is to provide a forum for idea exchange within the IGFS CB, AB and IAG Commission2 SC, towards the introduction of new and the update of old IGFS conventions and standards. The igfs-standards mailing list is open to all, but pending approval of the IGFS CB, given the more administrative nature of the list. The list can be accessed at https://lists.auth.gr/sympa/info/igfs-standards
Finally, IGFS has gained presence in public media, both in Facebook (@InternationalGravityFieldService) and Twitter (@igfscb) in order to increase both its visibility and the influence of its products.

**IGFS and GGOS**

- **Gravity metadata structure g-meta**

  The IGFS CB has developed, within the IGFS web-page, an IGFS-applications front-end where three main components have been established. The first one refers to the generation of metadata for both relative and absolute gravity observations, either original and gridded ones. The rest refers to metadata for geoid models as well as a geodatabase and geolocator for the visualization of all products offered by IGFS and its services.

IGFS generated a dedicated web-server hosted by a Virtual Machines Host (VMWare) of the Aristotle University of Thessaloniki targeting at minimum downtime, automatic backup and being monitored automatically for threats. The main technologies and modules employed for the metadata generation are HTML5, CSS3, javascript, jquery, php, netbeans and Modernizr. The application has succeeded to be lightweight, compatible with portable devices, adhere to user needs and extensible.

![The IGFS applications front-end (g-meta, N-meta and meta-Locator)](image)

*Technologies and modules used for the development of the IGFS metadata*
Moreover, it provides code in popular programming languages for integrating the functionality of g-\(\eta\)ta and N-\(\eta\)ta in existing applications. The g-\(\eta\)ta includes both mandatory and optional fields related to the gravity data acquisition standards, processing methodology, tide corrections applied, owner information, geospatial referencing etc. It requires a complicated validation procedure carried out both on the client and the server side.

Five main categories have been foreseen as: 1) Identification information, 2) Standards and conventions, 3) Data and Data quality information, 4) Distribution information and 5) Metadata reference information. All categories comply with ISO19115-1 adopted also by GGOS. The sub-categories within each main field are presented in the following figures.

- **The International Height Reference System/Frame**

The International Height Reference System/frame (IHRS/IHRF) is one of the key issues in IAG and GGOS. The proper estimation and modelling of global phenomena of the system Earth requires the definition of a reliable reference system/frame. This system/frame must be theoretically defined and established at a given level of precision and accuracy related to the studied phenomena. As it is well known, IAG provides the scientific community with the ITRSnn/ITRFnn. This global reference frame is a fundamental infrastructure that allows monitoring e.g geodynamical phenomena such as deformations of the Earth crust in seismogenic areas. At the moment, a corresponding physical reference system/frame for the reliable description of changes in the Earth’s gravity field is still missing. IGFS has been actively involved in the definition of such a system since the IHRS/IHRF is basically related
to the gravity field and its estimation. As a matter of facts, the aim of this project is to study the methodology for defining the IHRS and to realize it as global frame of points where the W(P) values are estimated. IGFS strictly co-operated with GGOS focus area on “Unified Height Systems” and Commission 2 on such topic and contributed to the paper by Ihde at al. (2017) that has been published on this subject on Survey in Geophysises. At the same time, IGFS is also involved in the definition of the Global Geodetic Reference System.Frame (GGRS/GGRS) that includes the definition of the new global gravity reference system that will replace IGSN71.

References

Recent IGFS activities
- 1st Joint IGFS and Section 2 meeting “Gravity, Geoid and Height Systems 2016”

The GGHS2016 “Gravity, Geoid and Height Systems 2016” Meeting was the first Joint Commission 2 and IGFS Symposium co-organized with GGOS Focus Area 1 “Unified Height System”. It took place in Thessaloniki, Greece between September 19-23, 2016 at the premises of the Aristotle University of Thessaloniki (Main Ceremony Hall of the Aristotle University of Thessaloniki). Its main focus was on methods for observing, estimating and interpreting the Earth gravity field as well as its applications.
GGHS2016 continued the long history of IAG’s Commission 2 Symposia, GGG2000 (Banff, Canada), GG2002 (Thessaloniki, Greece), GGSM2004 (Porto, Portugal), GGE02008 (Chania, Greece), GGHS2012 (Venice, Italy), with those of IGFS, 1st IGFS Meeting 2006 (Istanbul Turkey), 2nd IGFS Meeting 2010 (Fairbanks, Alaska, USA), 3rd IGFS Meeting 2014 (Shanghai, China) under a unified umbrella, the latter being decided during the XXVI IUGG General Assembly in Prague.
GGHS2016 was composed by 6 sessions spanning the entire 5 days of the program.

For GGHS2016, 211 abstracts have been received, out of which 94 have been scheduled as oral presentations and 117 as posters. 204 participants from 36 countries participated in the conference. It should be particularly emphasized that this symposium was able to attract also the young generation of scientists, since 35% of the total number of participants were either MSc Students or PhD candidates.
The scientific program of GGHS2016 was of outstanding quality and showed significant scientific advancements in several fields of gravity field research, which are briefly summarized in the following:

- **Session 1: Current and future satellite gravity missions**  
  (Chairs: Thomas Gruber and David Wiese)
  - For the satellite gravity mission GRACE continued improvements in data processing are still being achieved (better backgrounds models, Level 1 and Level 2 data processing). This generates steadily increasing interest in using GRACE products for societally-relevant decision making, such as drought/flood forecasting.
  - Therefore, the community is continuing to push for continuity and improved future gravity missions after GRACE-FO. Simulation efforts are being carried out to optimize such a mission in terms of data processing (reducing aliasing errors), instrument requirements, etc.
  - The continued assessment of GOCE data is leading to improved understanding of the measurement time series and influential environmental parameters.

- **Session 2: Global gravity Field Modelling**  
  (Chairs: Nikolaos Pavlis and Shuanggen Jin)
  - New modelling developments regarding high-resolution global gravity models (XGM2016, EGM2020) indicate significant improvement in accuracy. Component models of topography and isostasy are valuable tools for data reduction and geophysical interpretation.
  - Major advances have been achieved in computational methods, such as high-resolution modelling and solving large systems, and 2D Fourier series representation.
  - New and future data products (e.g., Antarctic polar cap, high-resolution marine gravity field) have become available, and innovative observation concepts based on relativity and quantum optics have been developed.

- **Session 3: Local/regional geoid determination methods and models**  
  (Chairs: Urs Marti and Hussein Abd-Elmotaal)
  - An improvement of the least squares collocation (LSC) technique with better inverse stability and covariance function sampling and representation, and also an iterative approach to better estimate covariances by a feedback approach, have been presented.
  - Major improvements of the analytical continuation technique of the gravity field have been made, aiming to stabilize the solution by smoothing the topography and take the effect of such smoothing as a forward modeling.
  - Also, an iterative approach for solving the fixed BVP has been adopted, aiming to reduce the memory requirement and needed CPU time.
  - Further improvements have been achieved in the activities of the IAG sub-commissions on gravity and geoid, e.g., in Europe and Africa.

- **Session 4: Absolute and Relative gravity: observations and methods**  
  (Chairs: Leonid Vituskin and Jakob Flury)
• Several highlights of innovative observations technologies have been presented, such as measurement results from test campaigns with a new French transportable quantum gravimeter.
• Very good and robust results from strap-down airborne gravimetry with a German system, flown side by side with a traditional Lacoste-Romberg sensor, could be achieved.
• Interesting absolute gravimetry campaigns from New Zealand and Saudi Arabia were undertaken.

- Session 5: Height systems and vertical datum unification
  (Chairs: Michael Sideris and Laura Sanchez)
  • Important considerations for the realization of the International Height Reference System (IHRS), especially, determination of potential values, time-dependent changes, consistency with the geometric coordinates, have been made.
  • Innovative approaches to determine gravity potential values with precise clocks have been proposed.
  • Strategies for the combination of different geodetic data (GNSS/levelling, gravity, GGMs, tide gauge registrations, MDT) for the vertical datum unification have been presented.

- Session 6: Satellite altimetry and climate-relevant processes
  (Chairs: Ole Andersen and Annette Eicker)
  • It could be demonstrated, that altimetry improves in precision due to new sensors and new geodetic missions, advancing our understanding particularly in coastal and artic regions.
  • Together with GOCE it brings new knowledge to oceanography.
  • New insights and refined understanding of mass transport processes on various timescales have been gained, and
  • advances in post-processing and optimum filter and leakage correction techniques for GRACE and future gravity missions have been made.

35 of the abstracts accepted and presented at the GGHS2016 conference (either oral or poster) have been submitted as papers for publication in the official peer-reviewed IAG Symposia Series at Springer Publisher.

- The 12th Geoid School

IGFS has been involved, together with ISG, in the organization of the 12th International Geoid School that was planned during the IAG/IUGG in Prague (June 2015). The school was held on June, 6th-10th, 2016, at Campus 5, Geodesy Department of Mongolian University of Science and Technology (MUST), Ulaanbaatar, Mongolia. The Local Organizing Committee was set up by the Mongolian University of Science and Technology (MUST), MonMap Engineering Services Co., Ltd, as a local hosting organizations, and the Mongolian Association of Geodesy, Photogrammetry and Cartography (MAGPC). 30 people attended this Geoid school. 15 students were from Mongolia and the remaining were from 9 different countries, namely: Bhutan, China, India, Latvia, Mongolia, Philippines, Poland, Russia and Sri Lanka.
During the four lesson days the following topics were discussed:

- General Theory on Gravity Field (F. Sansò)
- The Height Datum Unification (M. Sideris)
- Terrain Effect Computation and Remove/Restore (R. Forsberg)
- Residual Geoid Estimation (R. Barzaghi)
- Global Geopotential Models (S. Holmes)

**The Geomed2 Project**

IGFS has proposed and managed the GEOMED2 Project that started in 2015 and will end in mid 2018.

The main aim of the proposed GEOMED2 project is the determination of a high-accuracy and high-resolution geoid model for the Mediterranean Sea using land and marine gravity data and GOCE/GRACE based Global Geopotential Models. The processing methodology is based on the well-known remove-compute-restore method following both stochastic and spectral methods for the determination of the geoid and the rigorous combination of heterogeneous data. Within a pre-processing step, all available gravity observations for the wider Mediterranean basin has been collected, validated, homogenized and unified in terms of their horizontal and gravity system, so as to derive a gravity data base that is used for the determination of the geoid. The so-determined geoid model will form the basis for height-system unification within the Mediterranean Sea and will allow to derive high-resolution models of the Mean Dynamic Topography (MDT) to be used in estimating the circulation in the Mediterranean Sea.

The Mediterranean Sea has always been of economic and ecological importance to its surrounding countries. So, a better understanding of its currents is necessary for the management of fishery resources, potential pollution, and maritime security. In the context of this project, currents will be derived from the Mean Dynamic sea surface Topography (MDT), which will be calculated by subtracting the estimated geoid from the available high resolution Mean Sea Surface (MSS) models based on the combination of ERS-1/2, Envisat, TOPEX/Poseidon, Jason-1/2 and Cryosat-2 altimeter data.
The project is based on the cooperation between IGFS related Services (BGI, ICGEM, ISG) and the following scientific institutions:

- Politecnico di Milano, Italy
- Aristotle University of Thessaloniki, Greece
- GET UMR 5563, Toulouse, France
- SHOM, Brest, France
- OCA/Géoazur, Sophia-Antipolis, France
- DTU Space, Kopenhagen, Denmark
- General Command of Mapping, Ankara, Turkey
- University of Zagreb, Zagreb, Croatia
- University of Jaén, Jaén, Spain

Since the beginning of this project, which is financially supported by ESA, IGFS has organized four meetings in which the scientific problems related to the project topics were analysed and discussed. Presentations on GEOMED2 were given at EGU2016 and EGU2017 in Vienna. At the forthcoming IAG/IASPEI 2017 Conference in Kobe (Japan), four abstracts on the project have been submitted and accepted as oral/poster presentations.