

International Gravity Field Service - IGFS

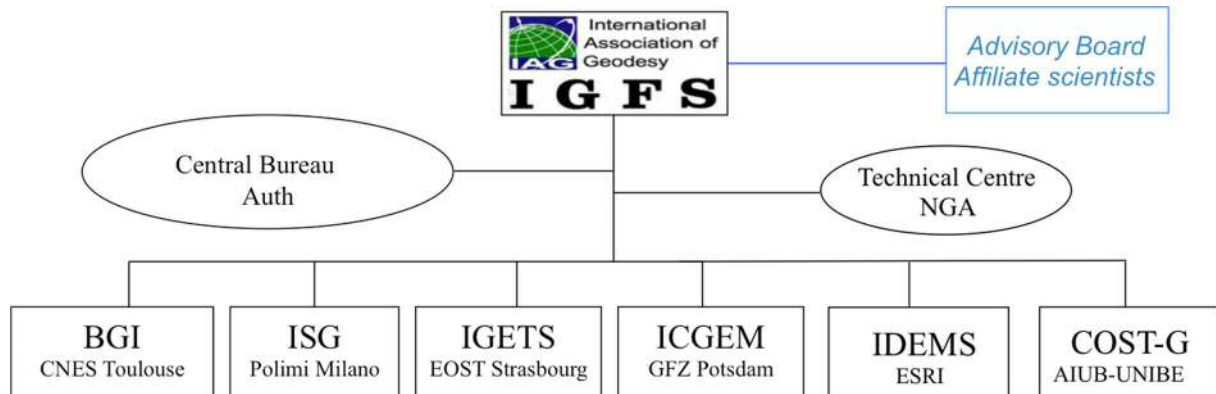
<http://igfs.topo.auth.gr/>

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 Gravimetric 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

COST-G (International Combination Center for Time-Variable Gravity Field Solutions), University of Bern, Bern, Switzerland

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, COST-G) 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)
- R. Forsberg (Denmark)
- T. Gruber (Germany)
- M. Reguzzoni (Italy)
- I. N. Tziavos (Greece)
- K. Kelly (USA)
- H. Abd-Elmotaal (Egypt)
- Y. Fukuda (Japan)

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 2015-2019, 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.

Furthermore, during 2018, a new service has been added to the IGFS structure. This is 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 new service under the IGFS umbrella. COST-G will provide monthly global gravity models in terms of spherical harmonic coefficients and derived grids. This will be done by combining solutions from different analysis centers based on GRACE/GRACE-FO data.

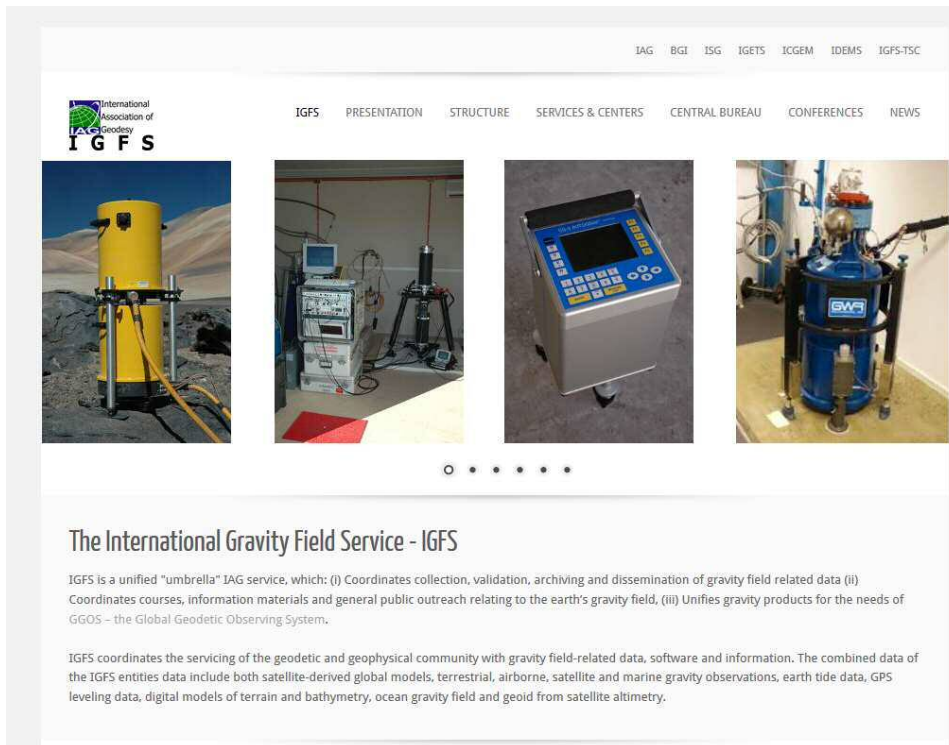
As mentioned, external actions were mainly performed in connection with GGOS activities. IGFS representatives attended the GGOS Days Meetings held in Frankfurt, Germany (October 21st-23rd, 2015), Cambridge, USA (October 24th-27th, 2016) and Vienna, Austria (October 11st-November 2nd, 2017). IGFS representatives have been also involved in the GGOS Bureaus meetings held in San Francisco (during AGU 2015, 2016) and Vienna (during EGU 2016, 2017, 2018, 2019). 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”. A second conference of this series has been then held in Copenhagen. On September 17th-21st, 2018, IGFS and Commission 2 co-organized there the 2nd Joint Commission 2 and IGFS Meeting

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.

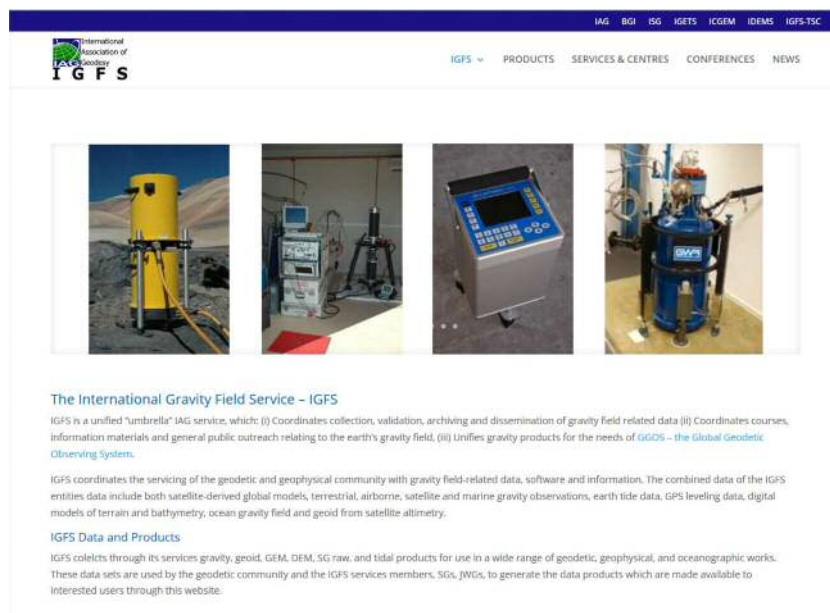
The IGFS Central Bureau and the IGFS web page

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.



The first update of the IGFS webpage online since April 2016

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.



<p>Gravity and geoid metadata</p> <p>Online applications for the creation of metadata for gravity and geoid data. Service for searching the metadata database.</p> <p>g-μeta the gravity metadata editor IGFS 1.0 – alpha released</p> <p>N-μeta the geoid metadata editor IGFS 1.0 – alpha released</p>	<p>Gravity data</p> <p>Land, marine, airborne gravity data as point and gridded values. Absolute and relative gravity data, WGM</p> 	<p>Geoid</p> <p>Geoid models and geoid determination software, geoid modeling processing methodologies</p> 
<p>Global Earth Models</p> <p>Collection and archive of all existing global gravity field models, web interface for access to GEMs, model visualization and service.</p> 	<p>Time-variable GEMs</p> <p>Combined gravity field solutions in SH coefficients and spatial grids for hydrological, oceanic and polar ice sheets applications.</p> <p>COST- Combination Service for Time-variable Gravity Models</p> 	<p>DEM data</p> <p>Digital Elevation Models, relevant software for DEM creation, assessment, manipulation and display, global relief and crustal models and spherical harmonic data sets.</p> 
<p>SG and Earth tide data</p> <p>Temporal variations of the Earth gravity field through long-term records from ground gravimeters, SG data, Earth tide data.</p> 		

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 is 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](mailto:igfs-standards@lists.auth.gr) 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

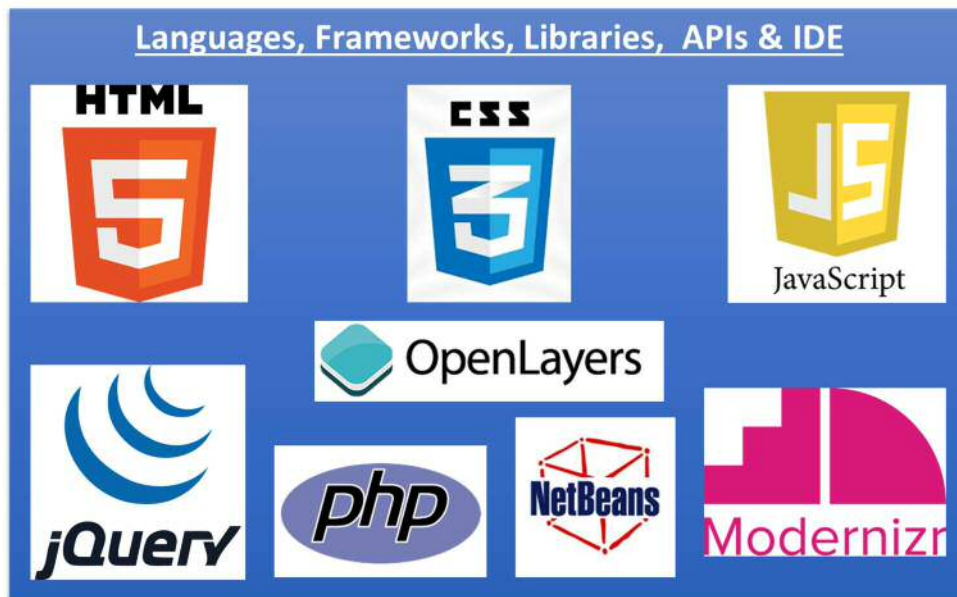
- Gravity metadata structure g-μeta

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, java scripting, 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-µeta, N-µeta and µeta-Locator)



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-µeta and N-µeta in existing applications. The g-µeta 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.

1. Identification Information	
Citation	
Description	
Time Period of Content	
Status	
Spatial Domain	
Keywords	
Constraints	
Points of Contact	
Security Information	

2. Standards and Conventions	
General Standards and Conventions	
Earth's Gravity Field	
Earth Orientation Parameters	
Tidal Conventions	
Station Coordinates and corrections for absolute gravity	

3. Data and Data Quality Information	
Attribute Accuracy	Gravity Data Type
Logical Consistency	Gravity Accuracy
Completeness Report	Position Accuracy

4. Distribution Information	
Distributor	
Standard Order Process	

5. Metadata Reference Information	
Metadata Creation Date and Creator Information	
Metadata Prototype Information	

Implemented categories within the IGFS g- μ eta metadata generator.

- 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 fact, 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 et al. (2017) that has been published on Survey in Geophysics. 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

Definition and Proposed Realization of the International Height Reference System (IHRS).
J. Ihde1, L. Sanchez, R. Barzaghi, H. Drewes, Christoph Foerste, Thomas Gruber, Gunter Liebsch, Urs Marti, Roland Pail, Michael Sideris, *Surv Geophys*, 2017, DOI 10.1007/s10712-017-9409-3.

Recent IGFS activities

- *1st Joint IGFS and Commission 2 meeting “Gravity, Geoid and Height Systems 2016”*



Thessaloniki, Aristotle University. 1st Joint Symposium of IAG Commission 2 and IGFS

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), GGEO2008 (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. The Symposium was organized in Sessions on the following topics:

- Session 1: Current and future satellite gravity missions
(Convenors: T.Gruber and D.Wiese)
- Session 2: Global gravity Field Modelling
(Convenors: N. Pavlis and S. Jin)
- Session 3: Local/regional geoid determination methods and models
(Convenors: U. Marti and H. Abd-Elmotaal)
- Session 4: Absolute and Relative gravity: observations and methods
(Convenors: L. Vituskin and J. Flury)
- Session 5: Height systems and vertical datum unification
(Convenors: M. Sideris and L. Sanchez)
- Session 6: Satellite altimetry and climate-relevant processes
(Convenors: O. Andersen and A. Eicker)

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.

- *2nd Joint IGFS and Commission 2 meeting: “Gravity, Geoid and Height Systems 2018”*



Copenhagen, “Black Diamond”. 2nd Joint Symposium of IAG Commission 2 and IGFS

The GGHS2018 “Gravity, Geoid and height Systems 2018”, the second Joint Symposium of IAG Commission 2 and IGFS, was held in Copenhagen, Denmark, between September 17-21, 2018 at the “Black Diamond”, which is part of the Royal Library of Copenhagen. The Local Organizing Committee was managed by the DTU-Space. The topics discussed in the Symposium were organized in seven sessions covering the following topics:

- Session 1: Current and future satellite gravity missions
(Convenors: T.Gruber and D.Wiese)
- Session 2: Global gravity Field Modelling
(Convenors: D. Roman and S. Jin)
- Session 3: Local/regional gravity field modelling
(Convenors: J.Agren and H. Abd-Elmotaal)
- Session 4: Absolute, Relative and Airborne Gravity: observations/methods
(Convenors: L. Vituskin and R: Forsberg)
- Session 5: Height systems and vertical datum unification
(Convenors: M. Sideris and L. Sanchez)
- Session 6: Satellite altimetry and applications
(Convenors: O. Andersen and X. Deng)
- Session 7: Mass transport and climate-relevant processes
(Convenors: C. Boening and A. Eicker)

87 oral presentations were given in the seven sessions during the 5 Symposium days while the 76 posters were displayed during the entire Symposium.

Papers from oral and poster presentations have been submitted to the Journal of Geodetic Science for a special issue that will be available by the end of 2019.

- 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.



The participants to the 12th International Geoid School, Ulaanbaatar, Mongolia

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)

Future geoid schools are foreseen in Iran and/or Argentina: contacts are ongoing with the Local Organizing Committees.

- The Geomed2 Project

IGFS has proposed and managed the GEOMED2 Project that started in 2015 and will end in 2019.

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, Copenhagen, 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, EGU2017 and EGU2018 in Vienna. Furthermore at IAG/IASPEI 2017 Conference in Kobe (Japan), four abstracts on the project have been accepted as oral/poster presentations.