The International Gravity Field Service (IGFS) and its components

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IGFS c/o DICA-Politecnico di Milano

Presented by
Thomas Gruber
Technical University of Munich, Germany
Member of the IGFS Advisory Board

GGOS Days 2019 & SIRGAS 2019
Rio de Janeiro, Brazil, 11\textsuperscript{th}-14\textsuperscript{th} November, 2019
The International Gravity Field Service (IGFS)
(http://igfs.topo.auth.gr/)

Director: Riccardo Barzaghi - CB Director: Georgios Vergos

Main IGFS tasks

IGFS is an “umbrella” IAG Service which:
- Coordinates collection, validation, archiving and dissemination of gravity field related data
- Coordinates courses, information materials and general public outreach relating to the Earth’s gravity field
- Unifies gravity products for the needs of GGOS
The IGFS structure

International Gravity Field Service (IGFS) – Director: R. Barzaghi
Central Bureau – Director: G. Vergos

International Gravimetric Bureau (BGI) – Director: S. Bonvalot

International Center for Global Earth Models (ICGEM) – Director: E. S. Ince

International Service for the Geoid (ISG) – President: M. Reguzzoni; Director: D. Carrion

International Geodynamics and Earth Tide Service (IGETS) – Director: H. Wziontek

International DEM Service (IDEMS) – K. Kelly

International Combination Service for Time-variable Gravity field solutions (COST-G) – A. Jäggi
The IGFS Central Bureau

The new Central Bureau was established on April 1st, 2016 (call at the beginning of 2016)

Director: Georgios S. Vergos

Scientific Consultants: Ilias N. Tziavos, Dimitrios Tsoulis, Christopher Kotsakis

Scientific Staff: Vassilios N. Grigoriadis, Dimitrios A. Natsiopoulos

Secretary: Dimitrios A. Natsiopoulos

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Web: http://igfs.topo.auth.gr/
The IGFS web page

The IGFS applications front-end (g-μeta, N-μeta and μeta-Locator @ IGFS web page)
IGFS-CB Online Apps

The on-line application for gravity and geoid metadata

**Overall Goals**

- Online application for creating metadata for gravity measurements
  \[ g\text{-}\mueta \]

- Online application for creating metadata for geoid models
  \[ N\text{-}\mueta \]

- Online application for discovering different type of information
  \[ \mueta\text{-}Locator \]
IGFS-CB Online Apps

General Setup

Web Server

URL: http://igfsapps.topo.auth.gr

Location: Virtual Machines Host (VMWare) of Aristotle University of Thessaloniki

- Minimum downtime
- Automatic backup
- Constantly monitored for threats
IGFS-CB Online Apps

General Setup

Web Server
Open Source Free Software

Low-cost solution
Reliable
Endorsed by users

all logos are trademarks of their respective owners
Development roadmap (g-μeta)

1. Prepare specifications according to needs
2. Prepare interface and test specifications
3. Adapt to ISO 19115-1 (common requirements)
4. Prepare interface and test specifications
5. Improve interface & include new capabilities
6. Public call for beta testing
7. Final product

Current status of g-μeta
Development roadmap (N-μeta)

1. Prepare specifications according to needs
2. Public call for beta testing
3. Prepare interface and test specifications
4. Adapt to ISO 19115-1 (common requirements)
5. Final product

Current status of N-μeta
Development roadmap (μeta Locator)

1. Request feedback from available IGFS data providers (e.g., BGI)
2. Design and implement test interface
3. Request feedback from IGFS
4. Assert service quality

Avoid overlapping of existing services

Current status of μeta-Locator
**Current progress (g-μeta) – Available Categories (1/3)**

1. **Metadata Reference Information**
   - Metadata Creation Date and Creator Information
   - Metadata Constraints
   - Metadata Prototype Information

2. **Identification Information**
   - Citation
   - Description
   - Status
   - Points of Contact
   - Keywords
   - Spatial Domain
   - Constraints and Security Information
### Current progress (g-μeta) – Available Categories (2/3)

<table>
<thead>
<tr>
<th>3. Distribution Information</th>
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<tbody>
<tr>
<td><strong>Distributor</strong></td>
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<td><strong>Standard Order Process</strong></td>
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<table>
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<tr>
<th>4. Standards and Conventions</th>
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<tbody>
<tr>
<td><strong>General Standards and Conventions</strong></td>
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<tr>
<td><strong>Earth’s Gravity Field Permanent Tide System</strong></td>
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<tr>
<td><strong>Earth Orientation Parameters Specifications</strong></td>
</tr>
<tr>
<td><strong>Tidal Conventions</strong></td>
</tr>
<tr>
<td><strong>Station Coordinates and Corrections (for absolute gravity)</strong></td>
</tr>
</tbody>
</table>
## 5. Data and Data Quality Information

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Information</th>
</tr>
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<tbody>
<tr>
<td>Attribute Accuracy</td>
<td>Logical Consistency</td>
</tr>
<tr>
<td>Completeness Report</td>
<td>Data Distribution</td>
</tr>
<tr>
<td>Gravity Data (type &amp; accuracy)</td>
<td>Time Period of Content</td>
</tr>
<tr>
<td>Position and Height Accuracy</td>
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</tbody>
</table>

**Current elements comply with ISO 19115-1**

IGFS & GGOS

- **IGFS representatives attended GGOS meetings:**
  - GGOS Days Meetings, Frankfurt, Germany (October 21\textsuperscript{st}-23\textsuperscript{rd}, 2015)
  - GGOS Days Meetings, Cambridge, USA (October 24\textsuperscript{th}-27\textsuperscript{th}, 2016)
  - GGOS Bureaus meetings held in San Francisco (during AGU 2015, 2016)
  - GGOS Bureaus meetings held in Vienna (during EGU 2016, 2017)

- **IGFS participates into the activities of the GGOS Focus area on “Unified Height System” for establishing the IHRS/IHRF**

- **IGFS is participating in the definition of the Essential Geodetic Variables (gravity)**
Joint IGFS&IAG-Commission2 scientific meetings

**The 1st Joint IGFS and IAG-Commission 2 meeting**
*GGHS2016*
Thessaloniki, Greece, September 19-23, 2016
(LoC: Aristotle University of Thessaloniki)

**The 2nd Joint IGFS and IAG-Commission 2 meeting**
*GGHS2018*
Copenhagen, Denmark, September 17-21, 2018
(LoC: DTU Space)

**The 3rd Joint IGFS and IAG-Commission 2 meeting**
*GGHS2020*
Austin, Texas, September 2020
(LoC: UT)

GGHS scientific topics

1) Current and future satellite gravity missions
2) Global gravity field modelling
3) Local/regional gravity field modelling
4) Absolute, Relative and Airborne Gravity - observations and methods
5) Height systems and vertical datum unification
6) Satellite altimetry and applications
7) Mass transport and climate-relevant processes
IGFS has proposed and managed the GEOMED2 Project that started in 2015 and will close at the end of 2019. The project is based on the cooperation between IGFS related Services (BGI, ICGEM, ISG) and other scientific institutions in the Mediterranean area.
Main activities of the Gravity Services
Bureau Gravimetrique International (BGI)
(http://bgi.obs-mip.fr)

Director : Sylvain Bonvalot

Main BGI tasks

- To collect, on a world-wide basis, all gravity measurements and pertinent information about the gravity field of the Earth
- To compile and store them in a computerized data base
- To redistribute them on request to a large variety of users for scientific purposes.
The gravity database at BGI

Relative land gravity measurements
(2,3 millions of data)

Relative marine gravity measurements
(10,5 millions of data)

Reference stations
(>4500 stations)

Absolute gravity measurements
The new International Gravity Reference System

BGI & IGETS Services
(existing databases in cooperation with BKG)

**Providing a long term & precise absolute gravity reference** at given stations (time variable gravity field)

- **Reference stations** with continuous monitoring (Superconducting or Quantum Gravimeter) preferred but no exclusive
- Should also includes
  - **GGOS Core stations**: Link to space geodetic techniques (GNSS, SLR; VLBI)
  - **Comparison sites**: with extended facilities for instrumental comparisons (meter traceability)

**Providing a worldwide infrastructure of absolute gravity values** (static gravity field)

- **Global dense network of AG stations** needs for referencing relative land & marine surveys
- **Progressive replacement of the IGSN71** (mostly based on relative measurements)
- Advantage of **increasing facilities for field AG measurements** (Ex: A10, Quantum ?)
- Expected support and collaboration from National agencies
Absolute gravity monitoring: where?
- AG/SG stations (cf. IGETS/GGP)
- Selected “Core” stations (cf. GGOS)

Absolute gravity values: where?
- Increasing number of field measurements (cf. BGI/BKG Agrav database)
- Increasing accuracy and accessibility w.r.t. IGSN71 network
International Centre for Global Earth Models (ICGEM)  
(http://icgem.gfz-potsdam.de/home)

Director : Elmas Sinem Ince

Main ICGEM tasks

- To collect and long-term archiving of existing global gravity field models
- To use standardized format in storing the models
- To develop tools for the visualization of the models
- To compute solutions from dedicated time periods (e.g. monthly GRACE models)
- To develop web-interface to calculate gravity functionals from the spherical harmonic models on selectable grids/user defined points
- To evaluate the global geopotential models
The available GGM at the ICGEM database

A screenshot from the table of topographic gravity fields in the website (18 models)

A screenshot of the list of available static gravity fields (175 models)

A screenshot of the list of the computed time varying solutions (e.g. monthly solutions)

A screenshot from the table of topographic gravity fields in the website (18 models)
The Calculation Service

Calculation of Gravity Field Functionals on Ellipsoidal Grids

Model selection
- Longterm Model
- Model from Series
- Topography related Model
- Celestial Object Model
- Topography

Grid selection

Functional selection
- height_anomaly
- height_anomaly_ei
- geoid
- gravity disturbance
- gravity disturbance sa
- gravity anomaly
- gravity_anomaly
- gravity_anomaly_ei
- gravity_anomaly_sa
- gravity_anomaly_bg

The height anomaly can be generalised to a 3-d function, (sometimes called "generalised pseudo-height-anomaly").

Here it is calculated on the ellipsoid, h=0, approximated by Bruns' formula (eqs. 78 and 118 of STR95/02).

Low-pass filtering by (gently) truncating the model (more details)

Start Gentle Cut: 70° Maximum Degree: 70°

Gaussian Filter (more details)

Definitions of the Filterlength σ

GGM computation on a given grid
The 3D visualization tool

Visualization of Gravity Field Models and their Differences

This is an interactive web site (based on JavaApplet) to visualize the Gecod and other gravity functions of the Earth. Please have some seconds patience for generating the image on the server.

The Geocod undulations are multiplied with a so-called radial basis factor (initial value b = 10,000) to make them visible.

You can select another Functional, gravity Model and Subband model (to display modal differences).

The option Grid defines the resolution of the view. Smaller values show more details, but require more computing time on the server.

EIGEN-6c4 model undulation (m)
Main ISG tasks

- To collect geoid estimates worldwide and to disseminate them among the scientific community
- To collect, test and, when allowed, to distribute software for the geoid determination
- To conduct researches on methods for the geoid determination
- To organize schools on geoid determination
- To disseminate special publications on geoid computations (e.g. lecture notes of the schools)
- To support Agencies or scientists in computing regional geoids
The local/regional geoid repository

- Almost 200 models are currently available in the ISG repository
- Each model has a dedicated webpage with some information

**South America (GEOID2015)**

**Authors:** D. Blickle, et al.
**Created:** 2015
**Resp.:** A.C.O.C. de Matos
**Status:** PUBLIC

**Description:**
The new South America geoid model has been computed on a 5° x 5° grid, by the remove-compute-resolve technique using 947,953 point gravity data (free-air gravity anomalies), the SANNs, u2 QTM for the computation of tension correction and other topographic and atmospheric effects. The mean free-air gravity anomaly (FA) in a 5° grid over land derived was from the complete FA over the ocean obtained from a satellite altimetry model DTU10. The short-wavelength component was estimated with FFT technique using the modified Stokes integral through spherical Molodenski-Meissl kernel modification. The reference field used was EGM2008 up to degree and order 260. The computed points are in a grid of 5° x 5° covering the area from 52.9503333° S to 14.5503333° N in latitude, and from 64.9503333° W to 30.0446667° W in longitude. The geoidal heights are referred to WGS84. Data are stored in grid format, i.e., parallelwise from N to S and W to E. (N° values in lat = 884, N° values in long = 780, total number of data = 673306).

**References:**

**Web of Science ID:**
D1O: DATA20160205012462778

Authors, year, distr. policy
Short description
Bibliographic reference
Web of Science index
Download and email links
Model visualization
Geoid models for South America

<table>
<thead>
<tr>
<th>Continent</th>
<th>Region</th>
<th>Authors</th>
<th>Year</th>
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<tbody>
<tr>
<td>Continental</td>
<td>South America</td>
<td>Blitzkow et al.</td>
<td>2010</td>
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<td>South America (GEOID2015)</td>
<td>Blitzkow et al.</td>
<td>2015</td>
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<tr>
<td>National</td>
<td>Argentina (GAR)</td>
<td>Corchete &amp; Pacino</td>
<td>2007</td>
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<td></td>
<td>Argentina (GEOIDEAR16)</td>
<td>Pinon et al.</td>
<td>2016</td>
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<td>Bolivia (BOLGEO)</td>
<td>Corchete et al.</td>
<td>2006</td>
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<td>Blitzkow et al.</td>
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<td>Blitzkow et al.</td>
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<td>Colombia (GEOCOL2004)</td>
<td>Sanchéz</td>
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<td>Uruguay (URUGEOIDE2000)</td>
<td>Subiza Piña</td>
<td>2000</td>
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<tr>
<td>Regional</td>
<td>Santa Fe Province - Argentina</td>
<td>Cornero et al.</td>
<td>2018</td>
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<td></td>
<td>Sao Paulo State - Brazil (GEOID-SP)</td>
<td>Guimarães et al.</td>
<td>2014</td>
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<td></td>
<td>Tierra del Fuego</td>
<td>Gomez et al.</td>
<td>2014</td>
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Merging national geoid estimations

Merging national geoid estimations

National geoid models residuals w.r.t. a global satellite-only model before applying the de-trending procedure, i.e. as they are stored in the ISG archive (units in m).

Residuals after the de-trending procedure (units in m).
The geoid schools and the training courses

- The First International School for the determination and use of the Geoid was organized in Milan (Italy) in 1994. Since then many other editions of the School followed.

- The last one was organized in Ulaanbaatar (Mongolia) in 2016.

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<td>Hungary</td>
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<td>Ecuador</td>
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<td>N° Students</td>
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<td>23</td>
<td>41</td>
<td>30</td>
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- In addition to the International Geoid School, ISG gives support to institutions and scientists by organizing, on request, specific training courses on geoid computation held at Politecnico di Milano.

Milan, Italy, 1994

Ulaanbaatar, Mongolia, 2016
Main ICET tasks

- To monitor temporal variations of the Earth gravity field through long-term records from ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors
- To continue the activities of the Global Geodynamic Project, to provide support to geodetic and geophysical research activities using superconducting gravimeter data within the context of an international network for field gravimetry, absolute gravity measurements and for tilt measurements
- To continue the activities of the International Center for Earth Tides
Data and products at IGETS

i) Several SG data are available at ISDC at GFZ:

- Raw gravity and local pressure records sampled at 1 or 2 seconds, in addition to the same records decimated at 1-minute samples (Level 1 products)
- Gravity and pressure data corrected for instrumental perturbations, ready for tidal analysis (Level 2 products)
- Gravity residuals after particular geophysical corrections (including solid Earth tides, polar motion, tidal and non-tidal loading effects) (Level 3 products)
- Corrected gravity data (Level 2) can also be found at Univ. of French Polynesia, along with the Bulletin d'Information des Marees Terrestres at [http://www.bim-icet.org/](http://www.bim-icet.org/).

ii) SG data for major Earthquakes (minute and second sampling)

iii) ATMACS, Atmospheric Attraction Computation Services at BKG

iv) mGlobe Matlab/Octave toolbox for computation of global hydrological, atmospheric and non-tidal ocean loading effects

v) EOST loading service (displacements, gravity, tilts)
IGETS SG data base containing data from 37 stations
Links of Reference Stations with IGETS, GGOS and IHRF

IGETS: links to stations with AG

GGOS: links to space geodetic techniques

IHRF: links with the height system
International Digital Elevation Model Service (IDEMS)  
(https://idems.maps.arcgis.com/home/index.html)

Director: Kevin Kelly

Main IDEMS tasks

- To provide a focus for distribution of data and metadata about digital elevation models (DEM)
- To provide spherical-harmonic models of Earth’s global topography
- To provide lunar and planetary DEM
- To provide relevant software for managing DEMs and related datasets.
Data and products at IDEMS

- Compilation of available national elevation data sets with information on data resolution, methods used for DEM generation and links to providers

- Generation and dissemination of spherical-harmonic models of Earth’s global topography and bathymetry

- Compilation of geodesy relevant DEMs studies

- Extension of the focus from Earth to Moon and terrestrial planets through compilation of information on available planetary topography models.

- Website managing in order to separate regional DEMs and global DEMs

- Ongoing updates of existing DEMs
Data and products at IDEMS

Geodesy Relevant DEM and BTM Studies

1 - 6, totale: 6

DEM and BTM Research Papers
PDF di chirt_IDEM52
Compilation of selected DEM and BTM (bathymetry) research papers relevant to geodesy. The list include papers on SRTM, ASTER, TanDEM-X and ALOS DEM and BTM with focus on the model generation, performance, accuracy and pitfalls.

PDF di chirt_IDEM52
Data creazione: 26 ott 2016    Aggiornamento: 26 ott 2017    Conteggio visualizzazioni: 56

Global Geospatial Data from Earth Observation (2016)
Document Link di lkeely_IDEM5
Overview paper on the status of global topography models.
Data creazione: 26 ott 2016    Aggiornamento: 12 set 2017    Numero di download: 19
International Combination Service for Time-variable Gravity Field Solutions (COST-G)  
(https://cost-g.org) 

Chair: Adrian Jäggi
Main COST-G tasks

The International Combination Service for Time-variable Gravity Fields (COST-G) is the Product Center of the International Gravity Field Service (IGFS) for time-variable gravity fields. COST-G provides consolidated monthly global gravity models in terms of spherical harmonic (SH) coefficients and thereof derived grids by combining solutions from individual Analysis Centers (ACs).

Recent Activities

- COST-G is currently working on the extension of combined GRACE monthly gravity field solutions (and also on combined Swarm monthly gravity field solutions)

- In January 2019 COST-G met in Bern at ISSI to further coordinate its upcoming activities.

- Preliminary combined solution presented at IAG/IUGG, Montreal (G03, July 14th)