Vol. 90 - No. 10 - October 2016

Journal of Geodesy

The Geodesist's Handbook 2016

International Association of Geodesy

A constituent Association of the

International Union of Geodesy and Geophysics (IUGG)

Edited by:

IAG Office
Hermann Drewes
Deutsches Geodätisches Forschungsinstitut
der Technischen Universität München (DGFI-TUM)
Arcisstraße 21
D-80333 München, Germany
Phone: +49-89-23 031 1215, Fax +49-89-23 031 1240
E-mail: iag.office@tum.de

Franz Kuglitsch
Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences
Telegrafenberg, A17
D-14473 Potsdam, Germany
Phone: +49-331-288 1978, Fax: +49-331-288 1759
E-Mail: fgkugl@gfz-potsdam.de

IAG Communication and Outreach Branch (COB)
József Ádám, Szabolcs Rózsa
Department of Geodesy and Surveying
Budapest University of Technology and Economics
P.O.Box 91
H-1521 Budapest, Hungary
Phone: +36-1-463 3222/3213, Fax +36-1-463 3192
e-mail: jadam@sci.fgt.bme.hu, szrozsa@iag-aig.org

International Gravity Field Service (IGFS)

Chair: **Riccardo Barzaghi** (Italy)
Director of Central Bureau: **Georgios Vergos** (Greece)

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

Objectives

IGFS is a unified "umbrella" IAG service, which will:

- Coordinate collection, validation, archiving and dissemination of gravity field related data;
- Coordinate courses, information materials and general public outreach relating to the Earth's gravity field;
- Unify gravity products for the needs of GGOS – the Global Geodetic Observing System.

The IGFS coordinates the following IAG services:

- 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.

The overall goal of IGFS is to coordinate the servicing of the geodetic and geophysical community with gravity field related data, software and information. The combined data of the IGFS entities will include global geopotential models, terrestrial, airborne, satellite and marine gravity observations, Earth tide data, GPS/leveling data, digital models of terrain and bathymetry, as well as ocean gravity field and geoid from satellite altimetry. Both the static and the temporal variations of the gravity field will be covered by the IGFS.

IGFS will – in cooperation with the Services - make a special effort in trying to secure release of data from national and international institutions holding data on the spatial and temporal gravity variations, geoid and the surface heights of the Earth, to make them widely available to the scientific community.

IGFS will coordinate regional conferences, tutorials and schools to train young scientists and members of national institutions in the various aspects of the gravity field science, computations, and data collection. IGFS will maintain a publication activity related to the gravity field, especially through "Newton's Bulletin".

Structure

The Service is organized by means of the following structure:

- Advisory Board;
- Central Bureau;
- Technical Centers;
- Services.

The Advisory Board is composed of:

- Directors (or their delegates) of each of the Services/Centers of IGFS;
- Chairs of the IGFS working groups;
- Presidents (or their delegates) of the IAG Commissions related to the Service work;
- A representative of the IAG Executive Committee (IAG-EC);
- Two members appointed among the affiliates.

The Advisory Board:

- Coordinates the scientific strategy;
- Coordinates the joint activity of the Centers;
- Oversees the participation of the Service in international projects;
- Presents to the IAG-EC proposals for associating new centers;
- Elects the IGFS affiliates upon nomination by the Services/Centers or affiliates.

The Advisory Board is appointed for four years between IUGG General Assemblies. The existing Advisory Board selects new members as required and nominates the Chair of the IGFS. The election is to be confirmed by the IAG-EC. The Advisory Board makes decisions by majority vote; it can also vote by email. The Advisory Board decides the Terms of Reference for IGFS.

IGFS Services and Centers

The IGFS Services and Centers are the "operating arms" of IGFS. They are committed to produce services and products related to the gravity field of the Earth and/or the planets and are approved by the IAG-EC. Services and Centers can include bodies of structures external to the IAG (e.g., the BGI which is reporting to FAGS). They will have their own governing bodies, nominated according to internal rules, also taking into account the interests of the supporting entities. In particular, each governing body will have a Director, elected according to internal rules.

Services and Centers will maintain a list of data and products, providing them to the general public according to their policy of dissemination. They will deliver services in the form of data archiving, data analysis and dissemination, software, training on gravity field estimation, support to field campaigns etc. The activities of each Service/Center will be reviewed annually by the IAG-EC. The IGFS Technical Centre, located at the National Geospatial-Intelligence Agency, USA, will play a special role in advice on global models, geoid and gravity, especially related to the global ultra-high resolution geopotential models.

IGFS Central Bureau

The IGFS Central Bureau will act as the central coordination and communication center of the IGFS. The Central Bureau will provide: a link between the IGFS entities, IAG, and external projects, networks or organizations (oceanic, atmospheric, hydrologic…); a link to the GGOS Bureaus in order to communicate their requirements and recommendations to the IGFS Services. It will also implement standards and recommendations related to gravity field observations, secure consistency with geometric standards and promote their use within the geoscience community. Furthermore, the Central Bureau will maintain the IGFS website and arrange gravity field related meetings and workshops.

Joint Study Groups

JSG 3.1: Intercomparison of Gravity and Height Changes (joint with Commissions 1, 2 and 3, description see Commission 3)

Joint Working groups

JWG 0.1.2: Strategy for the Realization of the International Height Reference System (IHRS)
(joint with GGOS, Commission 1, ICCT, description see GGOS)
Chair: Laura Sánchez (Germany)

JWG 2.1.1: Establishment of a global absolute gravity reference system (joint with Commission 2, description see Commission 2 and IGETS)
Chair: Hartmut Wziontek (Germany)

JWG 2.2.1: Integration and validation of local geoid estimates (joint with Commission 2, ISG, description see Commission 2)
Chair: Mirko Reguzzoni (Italy)

IGFS Advisory Board

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)
L. Vitushkin (Russia)
M. G. Sideris (Canada)
J. Huang (Canada)
A. Eicker (Germany)
R. Forsberg (Denmark)
T. Gruber (Germany)
M. Reguzzoni (Italy)
N. Tziavos (Greece)
K. Kelly (USA)
H. Abd-Elmotaal (Egypt)
Y. Fukuda (Japan)

International Centre for Global Earth Models (ICGEM)

Director: **Franz Barthelmes** (Germany)

http://icgem.gfz-potsdam.de

Terms of Reference

The determination of the Earth's global gravity field is one of the main tasks of Geodesy: it serves as a reference for geodesy itself, and it provides important information about the Earth, its interior and its fluid envelope for all geosciences. Thus, it is important to make the models of the global gravity field available to the public as products of geodesy. This becomes increasingly important as time variations of the global gravity field can be measured with better and better spatial and temporal resolution.

The calculation of the different functionals of the geopotential (e.g.: geoid, gravity anomaly, gravity disturbance, equivalent water height) from a defined global model, on a specified grid and with respect to a defined reference system, is far from being trivial and a responsibility of geodesy too.

Additionally, it is important to make the spatial structure and temporal variability of the global gravity field available to the general public in a graphic vivid manner. In particular for temporal gravity models, aspects of consistency in processing, reference frame, and parameterization are becoming more and more important.

Overview

The International Centre for Global Earth Models has been established in 2003 as a new service under the umbrella of the new International Gravity Field Service (IGFS) as one of six centers. It is mainly a web based service and comprehends:

- collecting and long-term archiving of existing global gravity field models; solutions from dedicated time periods (e.g. monthly GRACE models) are included;
- making them available on the web in a standardized format (self-explanatory);
- the possibility to provide Digital Object Identifiers (DOI) to the models, i.e. to the dataset of coefficients;
- the interactive visualization of the models (geoid undulations and gravity anomalies);
- the visualization of monthly GRACE models;
- a web-interface to calculate gravity functionals from the spherical harmonic models on freely selectable grids (filtering included);
- a web-interface to calculate and plot the time variation of the gravity field at freely selectable positions or over defined basins → the G^3-Browser (GFZ Grace Gravity Browser);
- the theory and formulas of the calculation service in STR09/02 (downloadable);
- the ICGEM web-based discussion forum;
- the comparison of the models in the spectral domain;
- the comparison of the models with GNSS / levelling derived geoid values;
- the visualization of surface spherical harmonics as tutorial.

Services

The Models

Currently, 153 models are listed with their references and, apart from 17 older models, all are available in form of spherical harmonic coefficients. Models from dedicated time periods (e.g. monthly solutions from GRACE) of CSR, JPL, CNES/GRGS and GFZ are also available. Since 2016 the models can be provided by Digital Object Identifiers (DOI).

Digital Object Identifiers (DOI)

Since 2016, ICGEM together with the Library of the "Wissenschaftspark Albert Einstein" (Telegrafenberg, Potsdam), provides the ability to assign Digital Object Identifiers (DOI) to the models, i.e. to the datasets of the coefficients.

The Format

The spherical harmonic coefficients are available in a standardized self-explanatory format which has been accepted by ESA as the official format for the GOCE project.

The Visualization

An online interactive visualization of the models (height anomalies and gravity anomalies) as illuminated projection on a freely rotatable sphere is available (see Fig. 1). Differences of two models, arbitrary degree windows, zooming in and out, are possible. Additionally, an animation over time of the monthly solutions from GRACE is also included. The visualization of single spherical harmonics is possible for tutorial purposes.

The G^3-Browser (GFZ Grace Gravity Browser)

To calculate and visualize the time variation of the gravity field at any desired point on the Earth or as mean over predefined basins, a specific web-interface has been developed. The results can be downloaded as plots or ASCII data. Figures 2 and 3 show two examples.

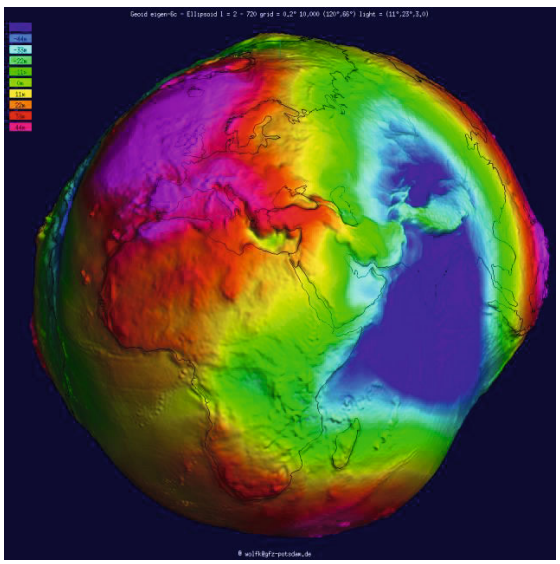

Fig. 1 Visualization (geoid) of a global gravity field model

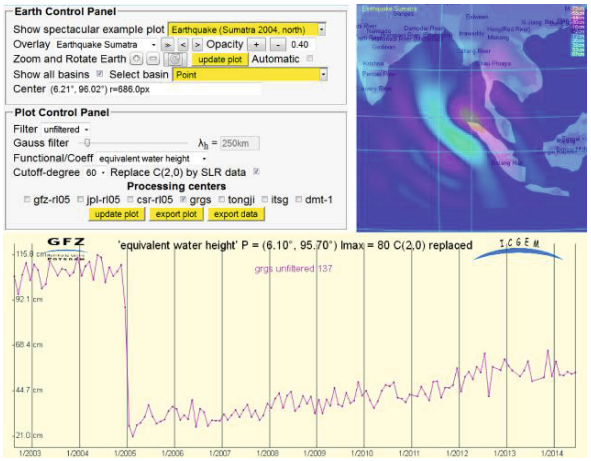

Fig. 2 Snapshot of the G^3-Browser; selected is a point affected by the Sumatra earthquake of 2004; the time series is computed from the GRGS monthly solutions

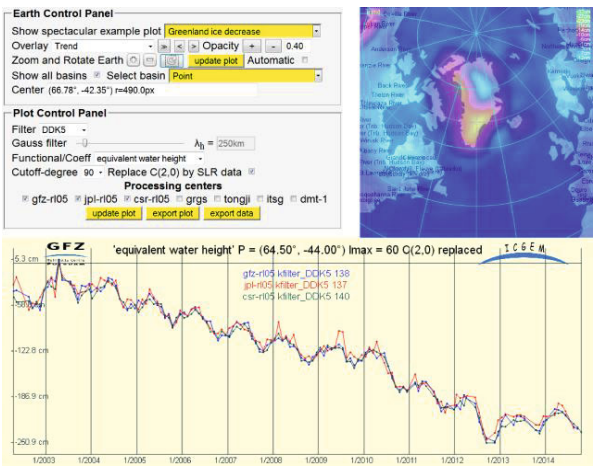

Fig. 3 Snapshot of the G^3-Browser; the plot shows the time series of the anisotropically filtered (DDK5) monthly solutions from GFZ, JPL and CSR at a point affected by the ice loss in Greenland

The Calculation Service

A web-interface to calculate gravity field functionals from the spherical harmonic models on freely selectable grids, with respect to a reference system of the user's choice, is provided (see Figs. 4 and 5). The following functionals are available:

- pseudo height anomaly on the ellipsoid (or at arbitrary height over the ellipsoid)
- height anomaly (on the Earth's surface as defined)
- geoid height (height anomaly plus spherical shell approximation of the topography)
- gravity disturbance

- gravity disturbance in spherical approximation (at arbitrary height over the ellipsoid)
- gravity anomaly (classical and modern definition)
- gravity anomaly (in spherical approximation, at arbitrary height over the ellipsoid)
- simple Bouguer gravity anomaly
- gravity on the Earth's surface (including the centrifugal acceleration)
- gravity on the ellipsoid (or at arbitrary height over the ellipsoid, including the centrifugal acceleration)
- gravitation on the ellipsoid (or at arbitrary height over the ellipsoid, without centrifugal acceleration)
- second derivative in spherical radius direction (at arbitrary height over the ellipsoid)
- equivalent water height (water column)

Filtering is possible by selecting the range of used coefficients or the filter length of a Gaussian averaging filter. The calculated grids (self-explanatory format) and corresponding plots (Postscript or Portable Network Graphics) are available for download after some seconds.

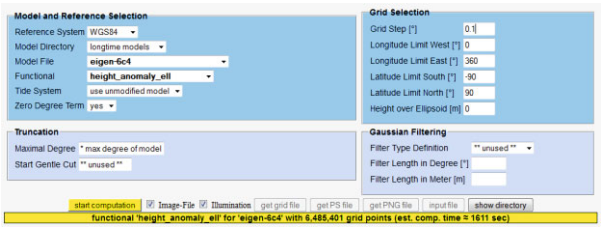

Fig. 4 Input mask of the calculation service

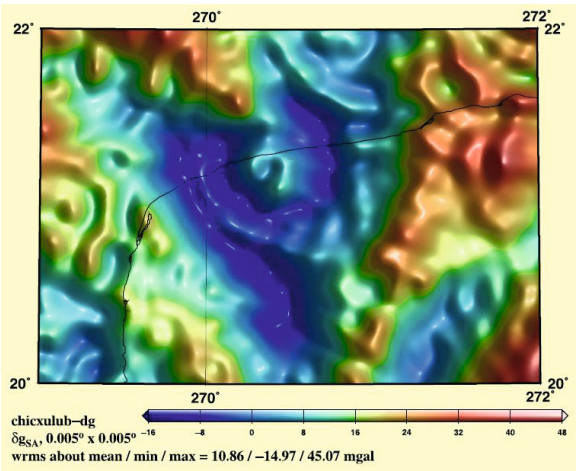

Fig. 5 Example of grid and plot generation by the calculation service: gravity disturbances of the Chicxulub crater region from the model EGM2008

The table is interactively re-sortable for all columns by clicking in the header cells.

Nr	Model	Nmax	USA 6169 points	Canada 2691 points	Europe 1047 points	Australia 201 points	Japan 816 points	Brazil 1112 points	All 12036 points
134	EIGEN-6C4	2190	0.247 m	0.126 m	0.121 m	0.212 m	0.079 m	0.446 m	0.2359 m
125	EIGEN-6C3STAT	1949	0.247 m	0.129 m	0.121 m	0.213 m	0.078 m	0.447 m	0.2364 m
138	GECO	2190	0.246 m	0.131 m	0.123 m	0.216 m	0.080 m	0.451 m	0.2370 m
117	EIGEN-6C2	1949	0.249 m	0.129 m	0.123 m	0.214 m	0.080 m	0.445 m	0.2373 m
112	EIGEN-6C	1420	0.247 m	0.136 m	0.128 m	0.219 m	0.082 m	0.448 m	0.2380 m
91	EGM2008	2190	0.248 m	0.128 m	0.125 m	0.217 m	0.083 m	0.460 m	0.2395 m
111	GIF48	360	0.319 m	0.209 m	0.229 m	0.236 m	0.275 m	0.474 m	0.3055 m
100	EIGEN-51C	359	0.335 m	0.234 m	0.248 m	0.234 m	0.312 m	0.476 m	0.3218 m
99	EIGEN-5C	360	0.341 m	0.278 m	0.266 m	0.244 m	0.339 m	0.524 m	0.3423 m
86	EIGEN-GL04C	360	0.339 m	0.282 m	0.309 m	0.244 m	0.321 m	0.541 m	0.3464 m
94	GGM03C	360	0.347 m	0.337 m	0.301 m	0.259 m	0.316 m	0.513 m	0.3566 m
81	EIGEN-CG01C	360	0.351 m	0.335 m	0.349 m	0.263 m	0.351 m	0.543 m	0.3682 m
84	EIGEN-CG03C	360	0.346 m	0.373 m	0.337 m	0.260 m	0.326 m	0.534 m	0.3702 m
131	GO_CONS_GCF_2_TIM_R5	280	0.398 m	0.310 m	0.343 m	0.336 m	0.450 m	0.505 m	0.3900 m
136	GOCO05S	280	0.399 m	0.308 m	0.344 m	0.335 m	0.450 m	0.505 m	0.3902 m
130	GO_CONS_GCF_2_DIR_R5	300	0.405 m	0.299 m	0.345 m	0.327 m	0.447 m	0.507 m	0.3918 m
118	GO_CONS_GCF_2_DIR_R4	260	0.404 m	0.322 m	0.372 m	0.337 m	0.476 m	0.512 m	0.4004 m
127	EIGEN-6S2	260	0.405 m	0.322 m	0.372 m	0.337 m	0.476 m	0.512 m	0.4010 m
135	GO_CONS_GCF_2_SPW_R4	280	0.406 m	0.330 m	0.375 m	0.322 m	0.473 m	0.508 m	0.4023 m
119	GO_CONS_GCF_2_TIM_R4	250	0.407 m	0.334 m	0.381 m	0.331 m	0.486 m	0.509 m	0.4053 m
104	GO_CONS_GCF_2_DIR_R1	240	0.407 m	0.342 m	0.384 m	0.319 m	0.489 m	0.499 m	0.4059 m
128	GOGRA04S	230	0.421 m	0.359 m	0.399 m	0.342 m	0.507 m	0.511 m	0.4207 m
129	JYY_GOCE04S	230	0.422 m	0.359 m	0.399 m	0.342 m	0.506 m	0.511 m	0.4212 m
115	GOCO03S	250	0.428 m	0.351 m	0.401 m	0.355 m	0.500 m	0.511 m	0.4226 m
113	GO_CONS_GCF_2_TIM_R3	250	0.430 m	0.350 m	0.399 m	0.357 m	0.496 m	0.512 m	0.4231 m
58	EGM96	360	0.379 m	0.353 m	0.493 m	0.298 m	0.364 m	0.730 m	0.4270 m
64	PGM2000A	360	0.381 m	0.360 m	0.503 m	0.286 m	0.362 m	0.717 m	0.4279 m
122	GOGRA02S	230	0.421 m	0.386 m	0.407 m	0.343 m	0.516 m	0.523 m	0.4288 m
114	GO_CONS_GCF_2_DIR_R3	240	0.431 m	0.369 m	0.408 m	0.355 m	0.506 m	0.515 m	0.4291 m
123	JYY_GOCE02S	230	0.422 m	0.386 m	0.407 m	0.344 m	0.516 m	0.522 m	0.4292 m
116	DGM-1S	250	0.441 m	0.348 m	0.413 m	0.366 m	0.513 m	0.517 m	0.4317 m
109	GOCO02S	250	0.435 m	0.366 m	0.420 m	0.371 m	0.516 m	0.525 m	0.4337 m
106	GO_CONS_GCF_2_TIM_R2	250	0.436 m	0.367 m	0.420 m	0.375 m	0.515 m	0.525 m	0.4344 m
120	ITG-GOCE02	240	0.429 m	0.391 m	0.422 m	0.371 m	0.511 m	0.524 m	0.4352 m
107	GO_CONS_GCF_2_DIR_R2	240	0.443 m	0.388 m	0.434 m	0.391 m	0.519 m	0.535 m	0.4448 m
137	GGM05G-UPTO210	210	0.448 m	0.374 m	0.454 m	0.357 m	0.543 m	0.521 m	0.4464 m
110	EIGEN-6S	240	0.446 m	0.392 m	0.434 m	0.397 m	0.520 m	0.539 m	0.4478 m
105	GO_CONS_GCF_2_SPW_R2	240	0.457 m	0.399 m	0.469 m	0.376 m	0.553 m	0.541 m	0.4603 m
101	GOCO01S	224	0.451 m	0.410 m	0.468 m	0.370 m	0.578 m	0.533 m	0.4605 m
103	GO_CONS_GCF_2_TIM_R1	224	0.455 m	0.417 m	0.470 m	0.371 m	0.578 m	0.530 m	0.4638 m
83	GGM02C	200	0.473 m	0.458 m	0.515 m	0.376 m	0.555 m	0.558 m	0.4865 m
102	GO_CONS_GCF_2_SPW_R1	210	0.471 m	0.471 m	0.496 m	0.384 m	0.569 m	0.554 m	0.4873 m
71	GGM01C	200	0.477 m	0.486 m	0.560 m	0.398 m	0.576 m	0.569 m	0.4975 m
63	TEG4	200	0.468 m	0.459 m	0.716 m	0.445 m	0.601 m	0.711 m	0.5277 m

Fig. 6 Table (truncated) of comparison of the models with GPS-levelling: Root mean square (rms) about mean of GPS / levelling minus gravity field model derived geoid heights [m]

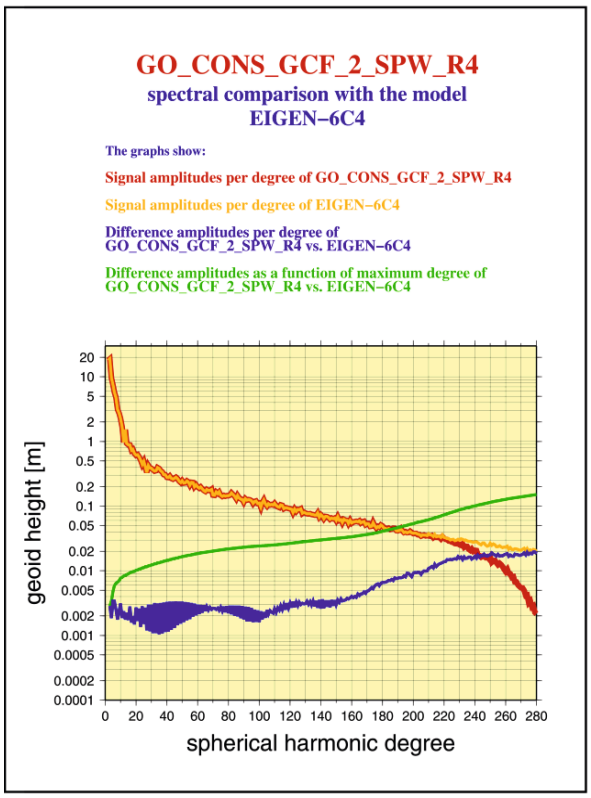

Fig. 7 Comparison of the models in the spectral domain (e.g.: GO_CONS_GCF_2_SPW_R4) with one of the most recent combination models (e.g. EIGEN-6C4)

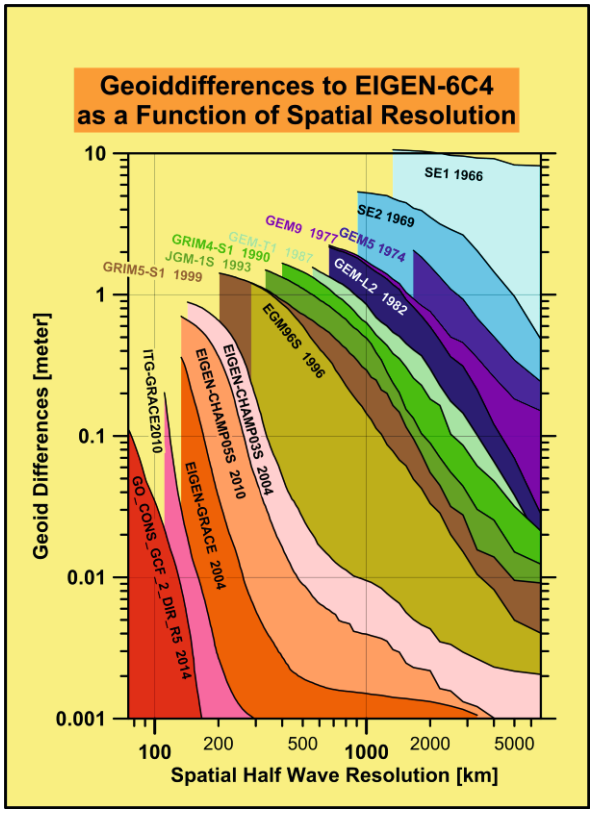

Fig. 8 Visualization of the improvement of satellite-only models over the past decades: Geoiddifferences to the model EIGEN-6C4 as a function of spatial resolution

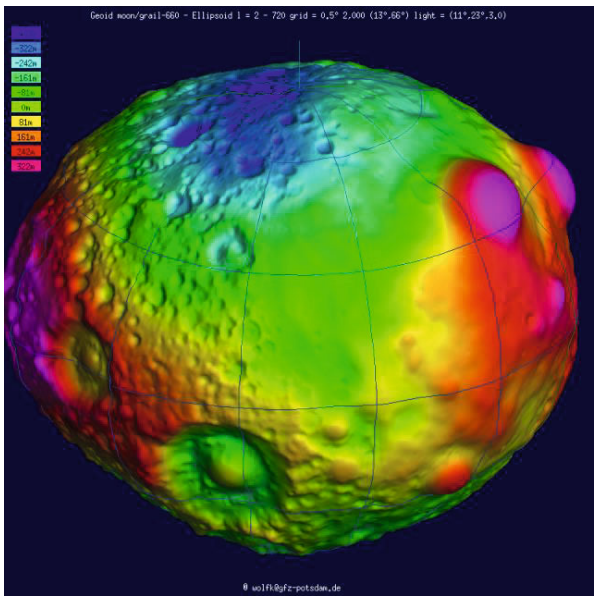

Fig. 9 Visualization of the "Geoid" of the Moon

Data Policy

Access to global gravity field models, derived products and tutorials, once offered by the center, shall be unrestricted for any external user.

Staff

ICGEM is hosted by GFZ Potsdam. Its staff consists of

- Franz Barthelmes
- Wolfgang Köhler

Point of Contact

Franz Barthelmes
Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences
Telegrafenberg
D-14473 Potsdam
Germany
E-mail: bar@gfz-potsdam.de