# International Centre For Global Earth Models (ICGEM)

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ICGEM website - https://icgem.gfz-potsdam.de/home

## 1 Introduction

The determination of Earth's global gravity field is one of the main tasks of geodesy: it serves as a reference for geodesy itself and provides essential information for all geosciences about the Earth, its interior and its fluid envelope. Thus, it is important to model the gravity field globally and make the state-of-the-art models available to public as geodetic products. With accurate satellite measurements, it is now possible to map the static gravity field as well as its variations with much higher spatial and temporal resolution compared to the first of its kinds. The list of such models is continuously growing and requires dedicated maintenance. The International Centre for Global Earth Models (ICGEM) is one of the five Services coordinated by the International Gravity Field Service (IGFS) of the IAG. The primary objective of ICGEM is to collect and archive all existing static and temporal global gravity field models and provide an online interactive calculation service for the computation of gravity field functionals, freely available to the general public. 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 or on points with respect to a defined reference system, is not trivial and is a responsibility of geodesy, too. Additionally, it is important to visualise the spatial and temporal distribution of the global gravity field and therefore interactive visualisation is also provided by ICGEM.

With the initiation of IGFS and the commitment for hosting and financial support by German Research Centre for Geosciences (GFZ), the ICGEM Service was established in 2003. Initially, it aimed to collect and archive static gravity field models. Due to the increasing interest of users and model developers, temporal gravity field models have also been made available on the same platform after the launch of GRACE mission. The service has been extensively used and promises further developments to serve multidisciplinary research. During the last couple of years, topographic gravity field models derived from digital elevation models and density estimations, combined temporal gravity field solutions, as well as simulated temporal gravity field models developed for the Mass change And Geosciences International Constellation (MAGIC) have also been made available by ICGEM. Apart from the growing data archive, the calculation service is also growing with new and updated tools such as G3 (GFZ GRACE Gravity) Browser dedicated to the calculation of temporal gravity field model series in terms of water column, gravity anomalies, and geoid, which is of educational importance.

## 2 Mission, Objectives

Over the years, the mission and objectives of the ICGEM Service have also grown and reshaped to better serve the community. ICGEM is designed as a web-based service and currently includes the following:

- collecting and long-term archiving of existing static global gravity field models, solutions from dedicated shorter time periods (e.g. monthly GRACE/ GRACE-FO models), topographic gravity field models and since 2023, simulated gravity field models of daily, weekly, and monthly scales;
- making the above-mentioned models available on the web in a standardized format as described in Förste et al. (2023) (https://icgem.gfz-potsdam.de/docs/ICGEM-Format-2023.pdf);
- since late 2015, the possibility of assigning Digital Object Identifiers (DOIs) to the models, static and time-varying coefficients of Earth's gravity field as well as topographic gravity field models;
- a web interface to calculate gravity field functionals from the spherical harmonic models on freely selectable grids and user-defined points;
- since 2023, G3 Browser to compare temporal gravity field series, with different filter and corrections applied (https://icgem.gfz-potsdam.de/g3);
- since 2024, a web interface to calculate the differences of gravity field functionals calculated based on two different long term gravity field models;
- since 2024, possibility to save and share the list of calculations requested together with their results in different data formats;
- a 3D interactive visualisation of the models (geoid undulations, gravity anomalies, and equivalent water heights);

- quality checks of the static gravity field models via comparisons with other models in the spectral domain and w.r.t. GNSS/levelling-derived geoid undulations;
- the visualisation of surface spherical harmonics as tutorial;
- the theory and formulas of the calculation service documented in GFZ's Scientific Technical Report STR09/02 (Barthelmes, 2013) (https://icgem.gfz-potsdam.de/docs/str-0902-revised.pdf);
- manuals and tutorials for global gravity field modeling and usage of the service (Barthelmes, 2014) (https://icgem.gfz-potsdam.de/docs/GlobalModelsEncyclopedia.pdf, for updated version see https://link.springer.com/referenceworkentry/10.1007/978-3-319-02370-0_43-3);
- scientific journal papers for educational and reference purposes (Ince et al. 2019) https://essd.copernicus.org/articles/11/647/2019/;
- the ICGEM web-based gravity field discussion forum (https://icgem.gfz-potsdam.de/guestbook) for questions on ICGEM and its products and for knowledge exchange.

# 3 Products

## The models

ICGEM relies on other centres and institutes who develop static and temporal gravity field models. By April 2024, *180 static gravity field models* are made available on ICGEM (http://icgem.gfz-potsdam.de/tom_longtime). Apart from 15 older models, the models are available in the form of spherical harmonic coefficients.

The list of *models from dedicated time periods* (e.g., monthly solutions from GRACE and GRACE-FO) is growing in parallel to the growing needs of relevant applications. Apart from the monthly models of Science Data System Centres CSR, JPL, and GFZ, various other solutions such as from CNES/GRGS and ITSG are also available. Also, the combined monthly models produced based on the IGFS COST-G (Combination Service for Time-variable Gravity Fields) standards have been made available (http://icgem.gfz-potsdam.de/series).

Upon request, *topographic gravity field models* have been made available for the first time in 2014 (http://icgem.gfz-potsdam.de/tom_reltopo). Such models can enhance the benefit from the gravity field products in high frequency components and in multidisciplinary studies such as in crustal modeling and terrain correction. Finally, since 2023, simulated temporal gravity field models developed based on different orbit configuration scenarios of MAGIC mission are available on the ICGEM Service (https://icgem.gfz-potsdam.de/sl/simulated).

## Digital Object Identifiers (DOI)

In order to support open science and open data, ICGEM does not only provide free access to the models but supports the assignment of *Digital Object Identifiers (DOI)* to make the models citable. Since 2016, ICGEM together with the GFZ Library and Information Services, provides a service to assign DOI to the models, i.e. to the datasets of the coefficients. Many recent gravity field models have already been assigned DOIs.

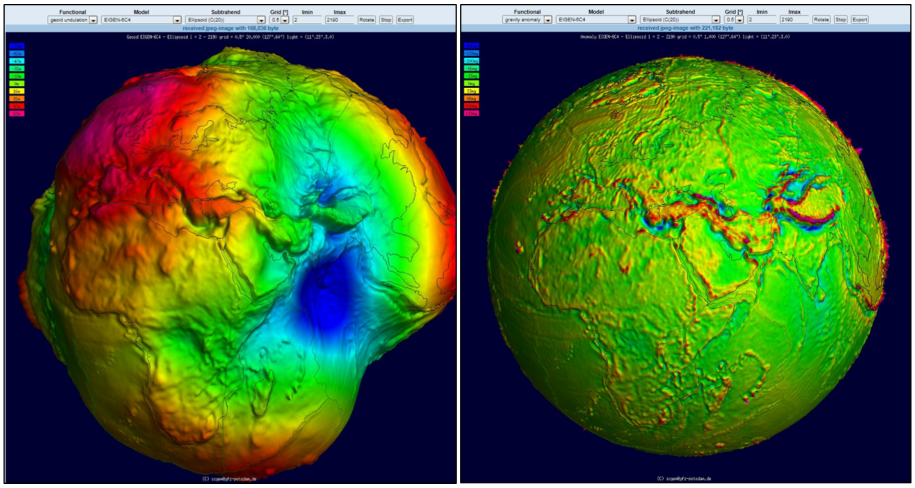

**Fig. 1.** Examples of the visualisation service for geoid undulation and gravity anomaly computed from a high-resolution combined static gravity field model

ICGEM encourages and supports model developers to request DOI at http://pmd.gfz-potsdam.de/panmetaworks/metaedit.

## The 3D visualisation

An online interactive service for the *visualisation* of the models (in terms of height anomalies and gravity anomalies) as illuminated projection on a freely rotatable sphere is available (http://icgem.gfz-potsdam.de/vis3d/longtime, see also Fig. 1). Differences between two models, arbitrary degree windows, zooming in and out, are possible. The visualisation of spherical harmonics is also possible for tutorial purposes (https://icgem.gfz-potsdam.de/vis3d/tutorial).

## The calculation service

A web-interface to *calculate gravity field functionals* from the spherical harmonic models on freely selectable grids or at user-defined points with respect to a reference system of the user's choice is provided. The following functionals are available in the grid calculation (http://icgem.gfz-potsdam.de/calcgrid) and can be downloaded in the ICGEM Format-XYZ Ascii, GeoTiff, and Surfer 7 Grid formats:

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

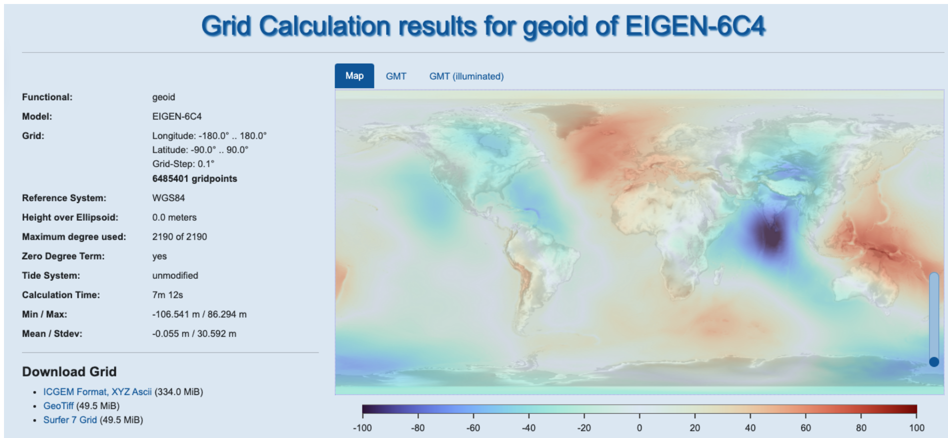


**Fig. 2.** Calculation service with updated visualisation and download options

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

Additionally, differences of any functional computed using two different models can also be calculated directly via selecting "Differences between two Longtime Models" under Model Selection.

Beside the functionals listed above, deflections of vertical can be computed at user-defined points (http://icgem.gfz-potsdam.de/calcpoints). In the calculation setting, filtering is possible by selecting the range of used coefficients or the filter length of a Gaussian averaging filter. The calculated grids together with the calculation settings in the header part can be downloaded once the calculation is completed. For grid calculations, the corresponding plots created using OpenLayers and GMT (in Portable Network Graphics format) are available for download. Since 2018, calculations on user-defined points are available and the results can be downloaded in ASCII format as well. An example of the newly designed calculation service is presented in Fig. 2.

## Evaluation

ICGEM continues to *evaluate the static gravity field models* w.r.t. GNSS/ levelling derived geoid undulations (https://icgem.gfz-potsdam.de/tom_gpslev) and in the spectral domain w.r.t. already reliable models (https://icgem.gfz-potsdam.de/evalm). The quality measures used in the evaluation pages will be improved in the future. Apart from the gravity field models of the Earth, ICGEM hosts similar models for other celestial bodies (Moon, Mars, Venus and Ceres).

### FAQs and Discussion Forum

In May 2017, to support the users from different disciplines and levels, ICGEM introduced the Frequently Asked Questions (FAQs) and their short and detailed answers. Such answers are expected not only to help students and researchers for educational purposes, but also to understand the background of the ICGEM products. Moreover, to increase the knowledge exchange with and among the users ICGEM's discussion forum is expanded so as to share gravity field related questions and information.

In December 2019, the ICGEM Subscription list was introduced: it is used to interact with the community and enhance the communication among the gravity field related scientists and students. News and updates are shared via this channel. The subscription (or unsubscription) can be performed via https://www.listserv.dfn.de/sympa/subscribe/icgemusers.

## 4 Program/Activities (2023-2027)

The current activities of ICGEM are mostly dedicated to meet the requirements of the users and model developers and outreach to all geosciences. ICGEM will be starting a new project, Service and Archive for Mass Distribution And mass Transport data (SAMDAT) in 2024 (https://gepris.dfg.de/gepris/projekt/527258067). The project aims to "respond to the growing need and community-derived demand for quality assured, well documented global gravity field models (GGMs) and related products with additional types of datasets that are enriched with metadata and provided in a sustainable and freely accessible research data infrastructure". Three new colleagues will join the ICGEM team for this purpose.

## 5 Structure

The ICGEM does not hold an official advisory board but items are discussed within the IGFS establishment.

### Staff

The ICGEM is organized by means of the ICGEM Team supported by GFZ-Potsdam. At the moment, this team consists of two members working on the scientific and technical development:

- E. Sinem Ince; Director of ICGEM, scientific support
- Sven Reißland; technical support

# 6 Point of Contact

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# 7 Publications, Meetings

ICGEM publishes IAG reports every two- and four-year terms. All ICGEM publications as IAG reports or conference presentations are available electronically on the website https://icgem.gfz-potsdam.de/home.

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