

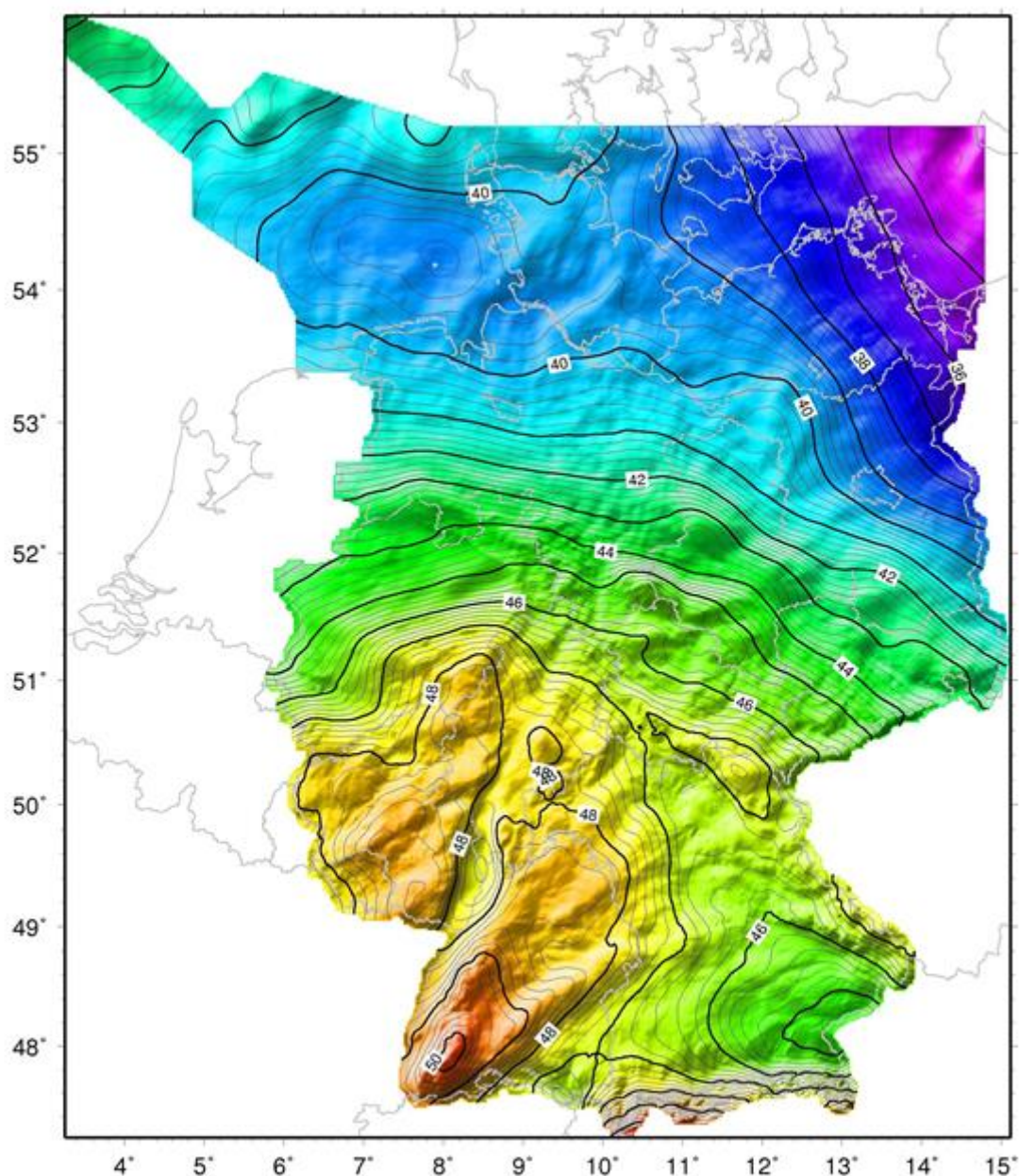


Quasigeoid of the Federal Republic of Germany

The height reference surface of the Working Committee of the Surveying Authorities of the
States of the Federal Republic of Germany

GCG2016

(German Combined QuasiGeoid 2016)



Status of documentation: 19 Feb 2021

Contents	Page
1 Dataset overview	3
2 Description of datasets	3
3 Data sizes	5
4 Information on conditions of data supply	5
5 Description of data formats	6
5.1 ASCII format	6
5.2 Binary format	6
5.3 Special formats for integration into software of equipment manufacturers	6
5.4 GeoTiff	7
6 Other	7
7 Ordering and other services	7

1 Dataset overview

Product:	GCG2016
Contents:	The German Combined Quasigeoid describes the authorized height reference surface of the German "Landesvermessung" above the reference ellipsoid of the Geodetic Reference System 1980 (GRS80). It can be used to transform ellipsoidal heights determined by GNSS observations into physical heights determined by leveling and vice versa.
Area:	Territory of the Federal Republic of Germany (cf. detailed information under 2.)
Spatial classification:	Grid file 30" x 45"
Georeferencing:	ETRS89 in the realization ETRS89/DREF91 (realization 2016) of the German national survey (ETRS89_Lat-Lon ¹ , position status 889) in relation to the reference ellipsoid GRS80 and leveling heights in the DHHN2016 (DE_DHHN2016_NH ¹ , height status 170)
Source:	<ul style="list-style-type: none">– gravity measurements– height anomalies at GNSS/leveling points– digital terrain models and bathymetric data– global geopotential models
Production method:	The product is computed by averaging two independent solutions of the BKG and the Institut für Erdmessung (Institute of Geodesy) of the Leibniz Universität Hannover (IfE). BKG: point mass adjustment, based on the "Remove-Compute-Restore" technique IfE: integration and collocation method based on the "Remove-Compute-Restore" technique
Resolutio:	Position: geographical latitude 30", geographical longitude 45" (approx. 0,9 km x 0,9 km) Height anomaly: 0,1 mm
Accuracy:	Height anomaly: < 1 cm (Alps max. 2 cm, marine area 2 – 6 cm)
Data formats:	<ul style="list-style-type: none">– ASCII (B, L, ζ)– Binary incl. interpolation program– Trimble format (.GGF)– LEICA format (.GEM)– TOPCON format (.gff)– SurvCE format (.gsf)– JAVAD format (.dat,.db3)– GeoTiff (.tif)
Data carrier:	DVD

2 Description of datasets

¹ Name according to "Coordinate Reference Systems and Units for AFIS-ALKIS-ATKIS" of the GeoInfoDok of AdV

The determination of the quasigeoid of the Federal Republic of Germany is a joint project of the State Survey Offices, the BKG and the IfE Hannover.

The quasigeoid allows the transformation between ellipsoidal heights in the ETRS89/DREF91 (realization 2016) and normal heights in the DHHN2016.

In Germany the official reference system ETRS89 is provided for users by means of the SAPOS station infrastructure. In case that ellipsoidal heights are provided by the SAPOS service leveling heights in the DHHN2016 can be computed without further corrections:

$$H^{DHHN} = h^{ETRS} - \zeta_{DHHN}^{ETRS}$$

The following data were used for the determination of the quasigeoid:

- gravity disturbances (δg) derived from 860 000 point gravity values obtained from the databases of the State Survey Offices, the BKG, the IfE Hannover, des Federal Maritime and Hydrographic Agency (BSH), the German Gravity Archive, the Employers' Association of Oil and Gas Production (WEG), the neighboring states of the Federal Republic of Germany and from the model DTU13 (Andersen et al., 2013) in marine areas
- approx. 470 quasigeoid heights (ζ_{SN}) derived from ellipsoidal heights from GNSS measurements at benchmarks in the ETRS89 and normal heights in the DHHN2016
- digital terrain models (Germany: DGM25, Europe: EuroDEM) and bathymetric data of the BSH and the worldwide model GEBCO (<http://www.gebco.net>, status 2004)
- global gravity field model EIGEN6C4 (Foerste et al., 2014)

The basis for the quasigeoid model are two independent computations of the BKG and the IfE. The computation method of the BKG is based on the adjustment of point masses in frame of a „Remove-Compute-Restore“ technique. The gravity measurements (gravity disturbances) are used as input data for the computations. These data were previously reduced i) by the gravitational influence of topography and ii) by the long-wavelength part of a global geopotential model. After the adjustment both parts are added again to the computed quasigeoid heights.

A grid of point masses in a depth of 5 km and a grid distance of approx. 5km is introduced as the unknown quantity to be determined. From the point masses determined in the adjustment a gravimetric quasigeoid is computed that is adjusted to the official reference systems ETRS89/DREF91 (realization 2016) and DHHN2016 by a correction surface. The correction surface is computed by an interpolation/collocation technique on the basis of a dataset of GNSS/leveling points that comprises approx. 470 points.

The quasigeoid computation of the IfE is based on the „Remove-Compute-Restore“ technique too. First in a two-step solution method free air anomalies and topographical data together with a global geopotential model are combined by an integration approach to a gravimetric solution of the quasigeoid. In a second computation step the GNSS and leveling heights are included by collocation approaches.

The computed quasigeoid heights of both models have a mean agreement of better than 0.5 mm; the standard deviation is 9.7 mm (land territory 4.6 mm). The final quasigeoid is obtained by averaging both model heights.

The model is provided for the whole area of Germany, alternatively for 5 subareas:

Northeast:	Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt, Thüringen
South:	Baden-Württemberg, Bayern
West:	Hessen, Nordrhein-Westfalen, Rheinland-Pfalz, Saarland
Northwest:	Bremen, Hamburg, Niedersachsen, Schleswig-Holstein
Coast:	Marine areas until 55.2° N or for the area of the exclusive economic zone of Germany (North Sea), respectively.

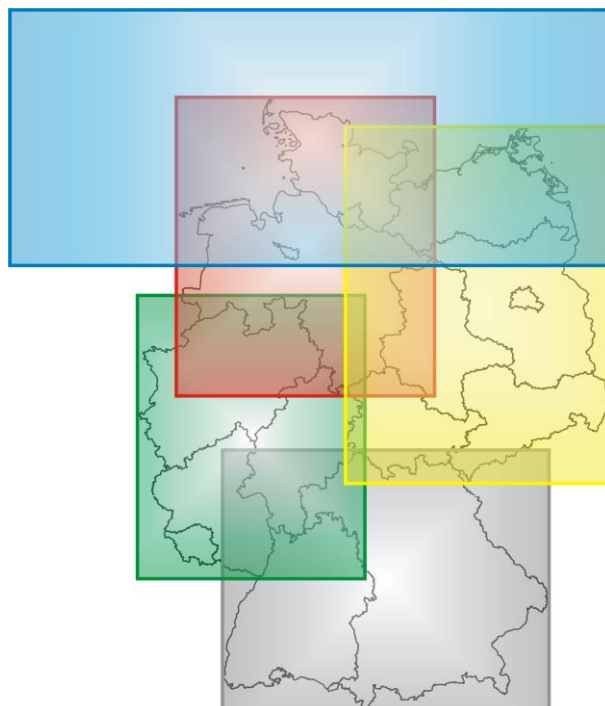


Fig.: Subareas of GCG2016

The grid width in each model is 30" x 45" in geographical coordinates.

Andersen, O. B., P. Knudsen, S. Kenyon, J. K. Factor, S. Holmes: The DTU13 Global marine gravity field – first evaluation; OSTST Meeting, Boulder (pres.), October 2103

Förste, C., Bruinsma, S. L., Abrikosov, O., Lemoine, J.-M., Marty, J. C., Flechtner, F., Balmino, G., Barthelmes, F., Biancale, R.: EIGEN-6C4 The latest combined global gravity field model including GOCE data up to degree and order 2190 of GFZ Potsdam and GRGS Toulouse; 5th GOCE User Workshop, Paris (pres.), November 2014

3 Data sizes

The data volume of the whole dataset is in the single data formats:

Specification	Data sizes	
	FRG total	Partial regions approx.
ASCII	29850 KB	9900 KB
Binary	3900 KB	1300 KB
GGF, gff	3900 KB	1300 KB
GEM	1900 KB	650 KB
gsf	8400 KB	2700 KB
db3	830 KB	300 KB
dat	1950 KB	500 KB
GeoTiff	3900 KB	1300 KB

4 Information on conditions of data supply

In all formats and for all regions the quasigeoid heights are only contained at raster points within the territory of the Federal Republic of Germany or in the area of the exclusive economic zone of

Germany (marine regions) according to the figure on page 1. Raster points situated outside of these boundaries contain a pseudo-value as quasigeoid height. Within the grid the quasigeoid heights are available in sorted form: 1st sorting according to descending geographical latitude, 2nd sorting according to ascending geographical longitude.

5 Description of data formats

5.1 ASCII format

The ASCII file contains one dataset per raster point consisting of the point position coordinates (in degrees) and the pertaining quasigeoid height (in m). The columns are separated by a blank space. As file extension ".txt" is used.

As pseudo-value outside the territory of the FRG for the quasigeoid height the value "999999." has been entered.

Example:

```
53.64583333 13.86875 36.4582
53.64583333 13.88125 36.4363
...
```

5.2 Binary format

The binary file of the quasigeoid heights consists of 4-byte values that have been stored continuously in series. The first 18 data fields form a header serving the description of the raster, which consists of 3 integer values each (degree, minutes, seconds*1000000) for min. geod. latitude, max. geod. latitude, min. geod. longitude, max. geod. longitude, grid distance in latitude, grid distance in longitude. Then the quasigeoid heights in 1/10 mm (or as binary 99999999 for pseudo-values applying outside the FRG) follow for the respective raster as real values.

In addition, an interpolation program serving the interpolation of quasigeoid heights at any points (within Germany) is supplied for this form (bicubic spline interpolation):

gintbs.exe Input: – File of the respective quasigeoid model
 – File with the coordinates of the points at which the quasigeoid height is to be interpolated. For this, it can be chosen between the input of lat and lon or lat, lon and ellipsoidal or normal height.
 – The file names are queried via dialogue.
 Output: – File with lat, lon and interpolated quasigeoid heights. Depending on the choice the computed normal height or ellipsoidal height follows.
 – The file name is queried via dialogue.

Example for a coordinate file:

```
49.027 11.287654987
51.2000001 13.9
48.55 9.0124
etc.
```

For the WINDOWS version there is a graphical interface "geoid.exe" available, which allows transformations between different coordinate systems in addition to the computation of quasigeoid heights too.

Content and handling are described in the file "geoid.readme".

5.3 Special formats for integration into software of equipment manufacturers

GGF: Special data format for integration into TRIMBLE Geomatics Office or TRIMBLE Business Center Software or for the utilization with TRIMBLE GNSS field receivers

GEM: Special data format for integration into LEICA Geo Office Software or for the utilization with LEICA GNSS field receivers

- gff: Special data format for integration into TOPCON Software or for the utilization with TOPCON GNSS field receivers
- gsf: Special data format (Carlson Geoid separation file) for integration into SurvCE Software
- db3: Special data format for integration into JAVAD applications (field, desktop, mobile)
- dat: Special data format for integration into JAVAD receiver firmware

5.4 GeoTiff

Special data format to for integration in GIS software (georeference EPSG:4258, created from binary format using GDAL version 2.4.3)

6 Other

The quasigeoid model is provided for the operating systems MS WINDOWS (XP/Vista/Windows 7/Windows 10) and LINUX. For each operating system the delivery comprises quasigeoid files in all mentioned data formats as well as an interpolation program and documentation.

A README-file contains information about the contents of the CD, advices for the installation and handling of the interpolation program.

A free online service to compute quasigeoid heights for single points is offered on the web page of the BKG at www.bkg.bund.de/geoid.

7 Ordering and other services

Orders can be placed via the **online ordering system** of the BKG under www.geodatenzentrum.de (only in German)

- [Produkte & Services](#)
- [Digitale Geodaten](#)
- [Geodätische Basisdaten](#)
- [Quasigeoid der Bundesrepublik Deutschland](#) (Direct link to the product page in the geodata shop)

or via the following address:

Bundesamt für Kartographie und Geodäsie
Dienstleistungszentrum
Karl-Rothe-Straße 10-14
04105 Leipzig

Tel.: +49 (0) 341 56 34 - 333
Fax: +49 (0) 341 56 34 - 415
E-Mail: dlz@bkg.bund.de

Further information and services can be found at www.geodatenzentrum.de.