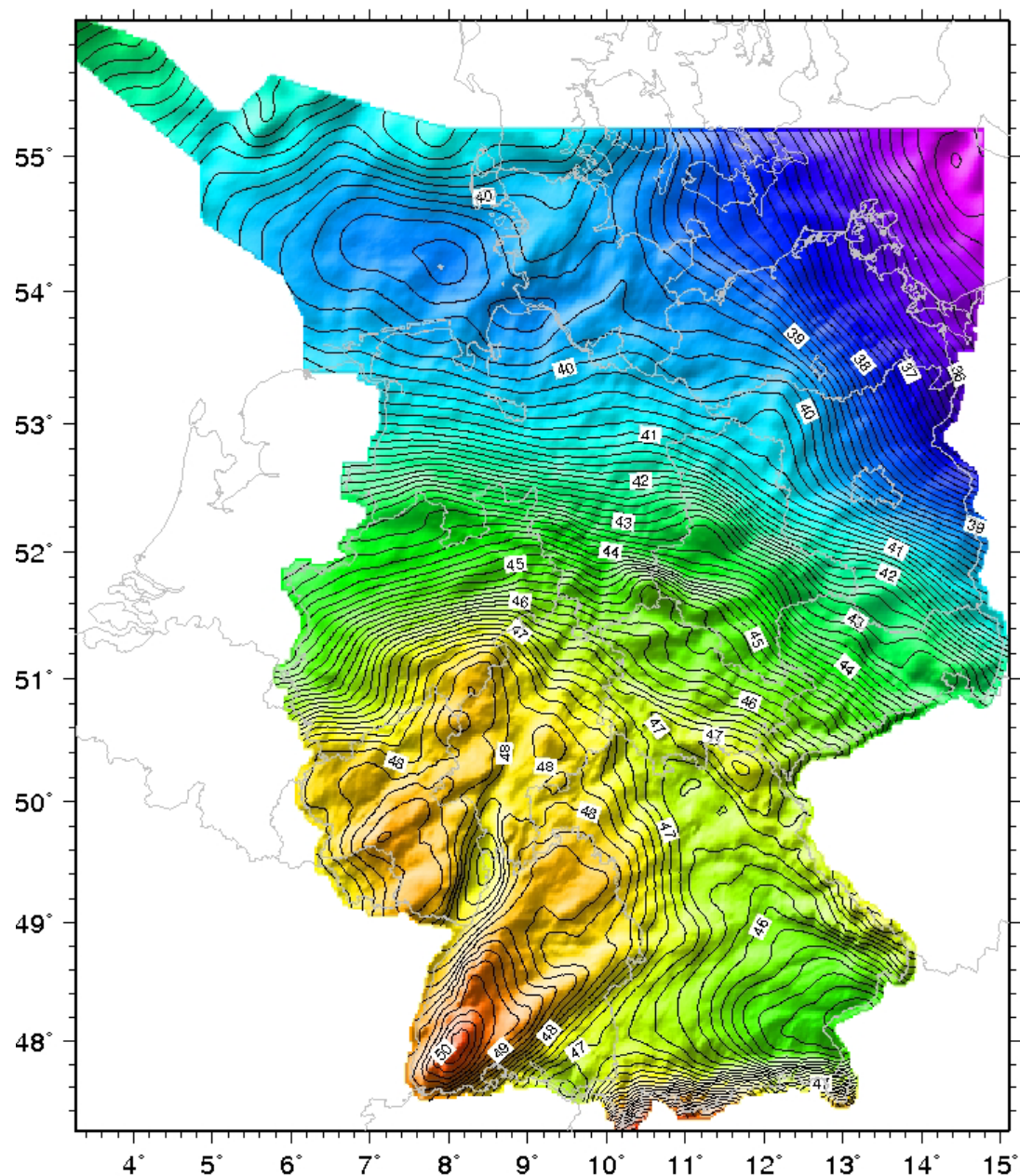


Quasigeoid of the Federal Republic of Germany

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

GCG2011

(German Combined QuasiGeoid 2011)



Status of documentation: 28.12.2011

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1 Dataset overview

Product	: GCG2011
Contents	: The quasigeoid model of the Federal Republic of Germany based on satellite-geodetic, leveling, and gravimetric data 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 1' x 1,5'
Georeferencing	: ETRS89 in the realization ETRS89/DREF91 of the German national survey (ETRS89_Lat-Lon ¹ , position status 889) in relation to the reference ellipsoid GRS80 and leveling heights in the DHHN92 (DE_DHHN92_NH ¹ , height status 160)
Source	: – 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
Resolution	: Position: geographical latitude 1', geographical longitude 1.5' (approx. 1.8 km x 1.7 km) Height anomaly: 1 mm
Accuracy	: Height anomaly: 1 – 2 cm (Alps 3 – 4 cm, marine area 4 – 10 cm)
Data formats	: – ASCII (B, L, ζ) – Binary incl. interpolation programme – Trimble format (GGF) – LEICA format (GEM) – SurvCE format (SOKKIA, gsf)
Data carrier	: CD-ROM

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

2 Description of datasets

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 and normal heights in the DHHN92.

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 DHHN92 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 645 000 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 DNSC08 (Andersen et al., 2010) in marine areas
- approx. 930 quasigeoid heights (ζ_{SN}) derived from ellipsoidal heights from GNSS measurements at benchmarks in the ETRS89 and normal heights in the DHHN92
- 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 models EIGEN5C (Foerste et al., 2008) and EGM2008 (Pavlis et al., 2008).

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 2' x 3' 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 and DHHN92 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. 930 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 3.4 mm (land territory 0.1 mm); the standard deviation is 16.4 mm (land territory 3.6 mm). The final quasigeoid is obtained by averaging both model heights.

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

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.

The grid width in each model is 1'x 1.5' in geographical coordinates.

Andersen, O. B., P. Knudsen and P. Berry (2010): *The DNSC08GRA global marine gravity field from double retracked satellite altimetry*. Journal of Geodesy, Volume 84, Number 3, DOI: 10.1007/s00190-009-0355-9.

Pavlis, N., S. Holmes, S. Kenyon, J. Factor (2008): *An Earth Gravitational Model to Degree 2160: EGM2008* - Presentation given at the 2008 European Geosciences Union General Assembly held in Vienna, Austria, April 13-18, 2008.

Foerste, C.; Flechtner, F.; Schmidt, R.; Stubenvoll, R.; Rothacher, M.; Kusche, J.; Neumayer, K.-H.; Biancale, R.; Lemoine, J.-M.; Barthelmes, F.; Bruinsma, J.; Koenig, R.; Meyer, U. (2008): *EIGEN-GL05C - A new global combined high-resolution GRACE-based gravity field model of the GFZ-GRGS cooperation*. General Assembly European Geosciences Union (Vienna, Austria 2008), Geophysical Research Abstracts, Vol. 10, Abstract No. EGU2008-A-06944, 2008.

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	7420 KB	1600 KB
Binary	980 KB	230 KB
GGF	980 KB	230 KB
GEM	490 KB	100 KB
gsf	1950 KB	400 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:

53.641667 13.8625 36.483

53.641667 13.8875 36.438

...

In this format the quasigeoid model is also read in with the TopconLINK software of the equipment manufacturer TOPCON for the use under TopSURV.

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 pseudovalues 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.

GEM: Special data format for integration into LEICA Geo Office Software

gsf: Special data format (Carlson Geoid separation file) for integration into SurvCE Software (SOKKIA)

6 Other

The quasigeoid model is provided for the operating systems MS WINDOWS (XP/Vista/Windows 7) 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

- *Online Shop*
- *Geodata Shop*
- *Product Selection*
- *Quasigeoid*

or via the following address:

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Referat GI5 - Dienstleistungszentrum
Karl-Rothe-Straße 10-14
D-04105 Leipzig

Tel.: +49(0)341 5634 333
Fax: +49(0)341 5634 415
E-Mail: dienstleistungszentrum@bkg.bund.de

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