A New Combined Height Reference Surface for Germany (GCG05)

Uwe Schirmer[1)], Heiner Denker[2)], Johannes Ihde[1)], Gunter Liebsch[1)], Jürgen Müller[2)]

[1)] **Bundesamt für Kartographie und Geodäsie (BKG)**

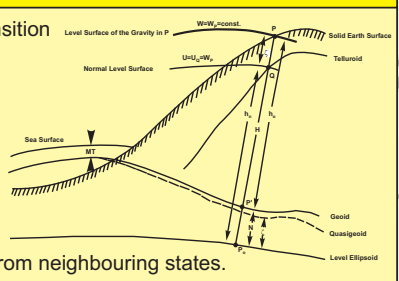
[2)] **Institut für Erdmessung, Universität Hannover (IfE)**

In a joint effort, BKG and IfE developed a new model for the height reference surface (quasigeoid) in Germany, which now serves as a standard for the conversion between GPS ellipsoidal heights and normal heights. BKG and IfE did independent computations based on two different methods, which both rely on the remove-restore technique and combine a global geopotential model, point gravity data with a spacing of a few km, a digital terrain model with a block size of 50 m as well as GPS and levelling control points. Due to insignificant differences between the two independent solutions, both results are simply averaged, yielding the final model GCG05. The evaluation with independent GPS and levelling results suggests that the accuracy of the GCG05 model ist about 1 to 2 cm.

Objective

- Determination of a height reference surface for the transition between the official German coordinate Systems (Position: ETRS89, Normal Heights: DHHN92) with an accuracy of 1 - 2 cm.

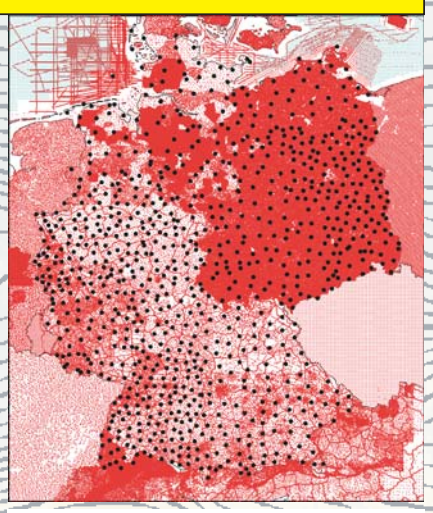
$$H^{DHHN} \quad h^{ETRS} - {}^{ETRS}_{DHHN}$$



- Implementation on the basis of GPS/levelling measurements and gravity measurements from the Surveying Authorities of the German federal states and additional gravity measurements within Germany and from neighbouring states.
- The height reference surface is adjusted to the latest realization of ETRS89 in Germany. This realization of ETRS89 guarantees an optimal fit to the reference frame realized by the Satellite Positioning Service SAPOS. The adjustment was realized by the Surveying Authorities of the German federal states by different ways.

Data basis

- 895 points with GPS and levelling measurements with a distance of 20 km to 30 km
- appr. 430 000 gravity measurements from Germany and the neighbouring states (from Poland, Czech Republic and Luxembourg only mean free-air anomalies are available) and mean free-air anomalies at sea areas (model KMS02, derived from altimeter measurements)
- A digital terrain model (DGM25 with a basis resolution 50 x 50 m within Germany, DTED level1 with a basis resolution 90 x 90 m outside Germany)
- The global geopotential model CG01C from GFZ Potsdam



GPS/levelling measurements (black) and point gravity measurements (red)

Method

- **BKG**

  The method is based on the point mass modelling technique, where the residual gravity and height anomaly observations are used in a common adjustment to determine the point masses at pre-determined positions. The point masses are arranged at 3 levels and grids:

  – 2' x 3' at 5 km depth
  – 0.2° x 0.3° at 30 km depth
  – 1° x 1,5° at 200 km depth

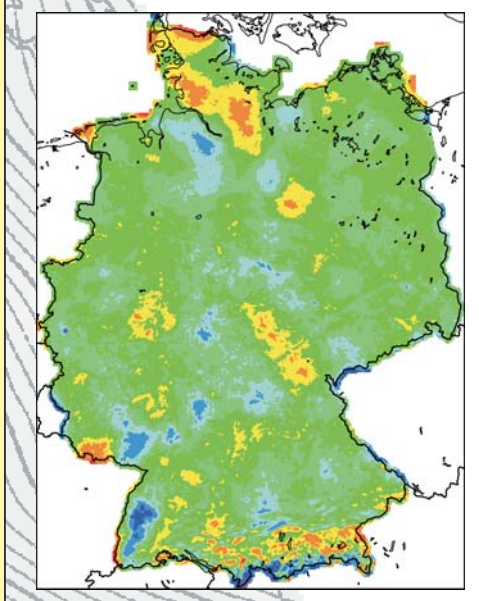
- **IfE**

  The modelling uses a two-step procedure. At first, the gravity and terrain data are combined with a global geopotential model using the least squares spectral combination technique with integral formulas, while subsequently a smooth corrector surface is developed from the GPS/ levelling data by least squares collocation. The corrector surface is added to the gravimetric quasigeoid, yielding the final height reference surface.

- **Remove-restore technique**

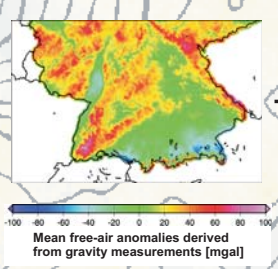
  At both methods the observations are reduced by the influence of the topography and a global geopotential model (CG01C of GFZ Potsdam) before the computation and also added again to the final modelled quasigeoid heights.

- **Averaging of both quasi geoid models**

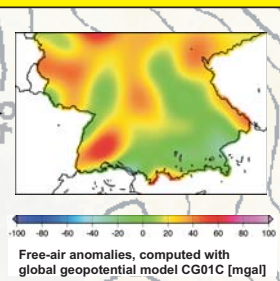


Model differences between BKG and IfE [mm]

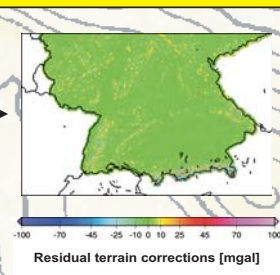
Steps of the Remove-restore im Southern Germany



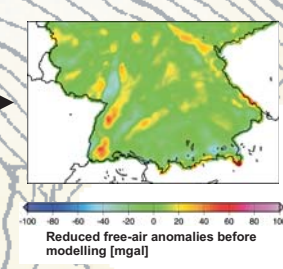
Mean free-air anomalies derived from gravity measurements [mgal]



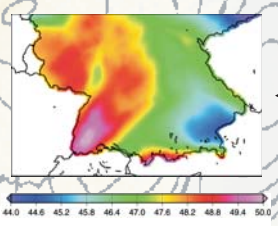
Free-air anomalies, computed with global geopotential model CG01C [mgal]



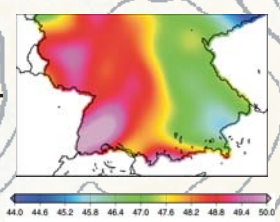
Residual terrain corrections [mgal]



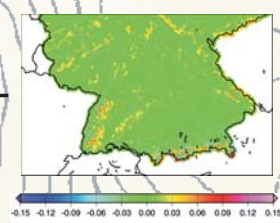
Reduced free-air anomalies before modelling [mgal]



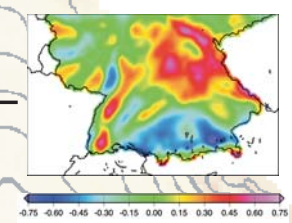
Final quasigeoid heights [m]



Geoid heights, computed with global geopotential model CG01C [m]



Residual terrain corrections [m]



Resulting geoid heights after modelling [m]

Results

- Comparison of the solutions BKG / IfE (mm):

	BIAS	RMS	Min.	Max.
Germany	-0.1	4.9	-61	36

  – model differences > 4 cm occur only within the Alps
  – systematic differences at the German borderline result mainly from different sets of gravity data (mean free-air anomalies Poland, Czech Republic, Luxembourg / Austria)

- Only 50 % of the GPS/levelling measurements are used for a modelling by the BKG method, the other 50 % are interpolated within the resulting model. 95 % of the points are approximated better than 2 cm, 70 % better than 1 cm.

- Existing independent comparative measurements in 2 mountainous areas (Harz/Estergebirge) show the following differences (mm):

	BIAS	RMS	Min.	Max.
A) Harz, 26 points				
BKG 2005	-1.4	6.9	-19	8
IfE 2005	1.3	7.0	-16	14
GCG05	-0.1	6.6	-17	10
B) Estergebirge, 54 points				
BKG 2005	49.6	15.3	4	77
IfE 2005	63.3	15.5	21	89
GCG05	56.4	14.6	12	82

  (The GPS heights are ***not*** related to the SAPOS level, this is the reason for the amount of the BIAS)