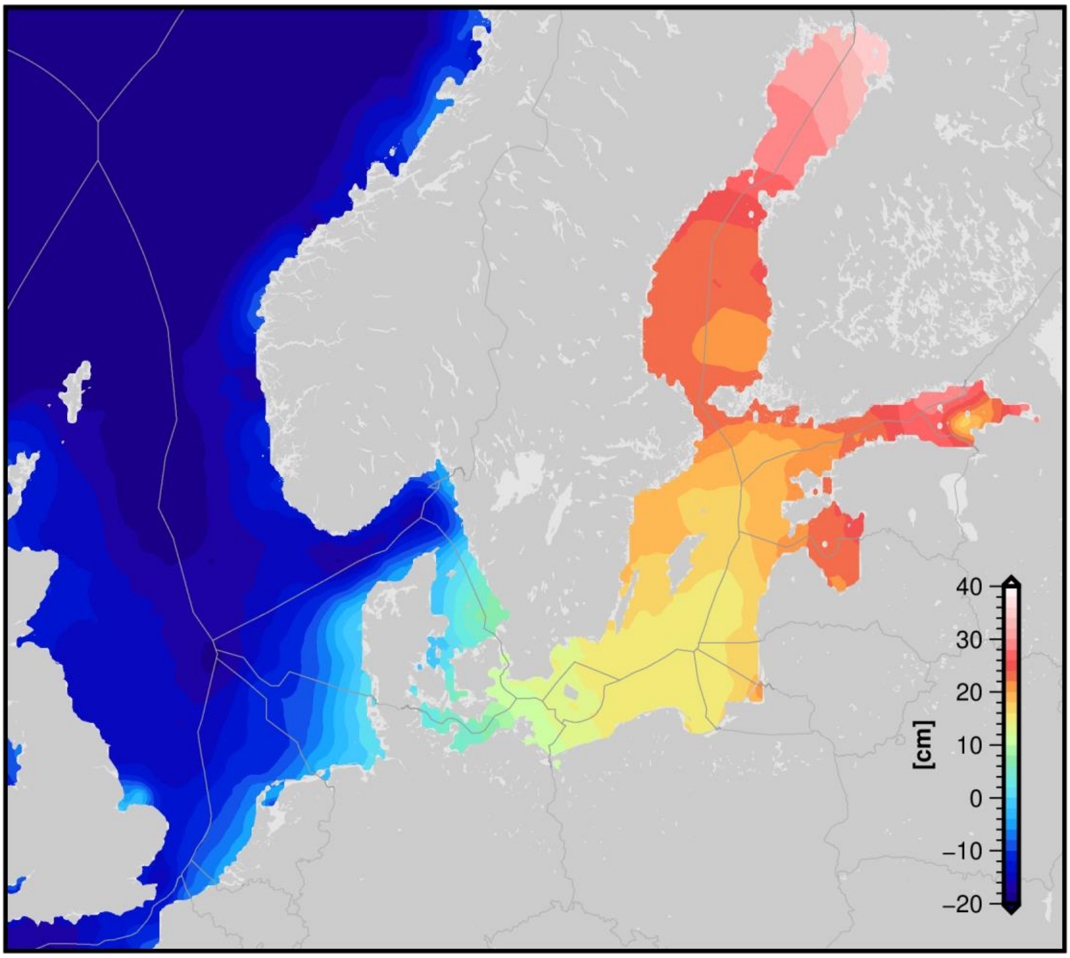
Bundesamt für
Kartographie und Geodäsie

Documentation

Mean Sea Surface Height of North and Baltic Sea (MS-Flaeche)

Product as of 11 2025



Content

1 Overview

Product:	Mean Sea Surface Height of North and Baltic Sea
Content:	The mean sea level describes the long-term average water level above the geoid/quasi-geoid as a geodetic reference surface. It is based on satellite altimetry measurements since 1992 and refers to the reference epoch 2008.45 (June 2008 – corresponding to the mean measurement epoch of DHHN2016). The product includes two variants for different areas of application: a) For applications in the official German height system (height reference surface GCG2016) b) For cross-border scientific applications (gravimetric height reference surface - geoid) The differences are in the range of a few centimeters.
Area:	German EEZ (3° – 15.7° E, 52° – 56.1° N) North and Baltic Sea (-5° – 31° E, 48° – 66° N)
Spatial structure:	Grid files for the respective area
Spatial reference:	Position: EPSG:4326 (WGS84, ellipsoidal coordinates) Height: a) EPSG:7837 (DHHN2016) b) Height above geoid on NAP level
Height accuracy:	Relative: some mm Absolute: 4 cm (Standard deviation from comparison with tide gauges)
Currentness:	2025-11
Resolution:	ca. 10 km (0.10° latitude, 0.15° longitude)
Data formats:	NetCDF, GeoTiff
Data supply:	Download
Data volume:	1,5 MB
Data source:	https://sgx.geodatenzentrum.de/web_public/gdz/datenquellen/datenquellen_ms-flaeche.pdf

2 Description

2.1 Content and format

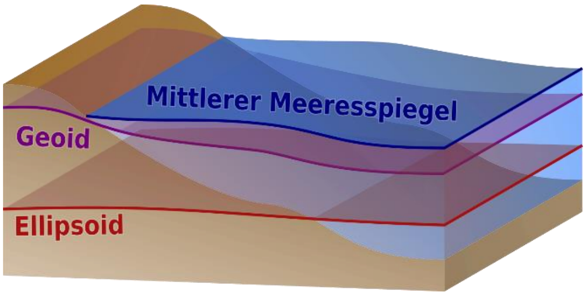


Figure 1: Height reference surfaces near the coast

The reference surface for physical heights, the geoid, describes an equipotential surface of the Earth's gravitational field.

The mean sea level also follows the Earth's gravitational field, but its height is additionally influenced by dynamic factors such as wind, air pressure, ocean currents, etc. The effect of these dynamic influences leads to a deviation of the mean sea level from the geoid and is also referred to as “mean dynamic topography” (MDT). Globally, these deviations can be up to two meters, while in Northern Europe they reach magnitudes of up to half a meter. This product provides grids of mean sea level height over the following reference surfaces.

2.1.1 Versions of the products

There are two variants available for different areas of application:

a) “gcg”: Mean sea level for applications in the official German height system (height reference surface GCG2016)
b) “grav”: Mean sea level for cross-border scientific applications (gravimetric height reference surface - geoid)

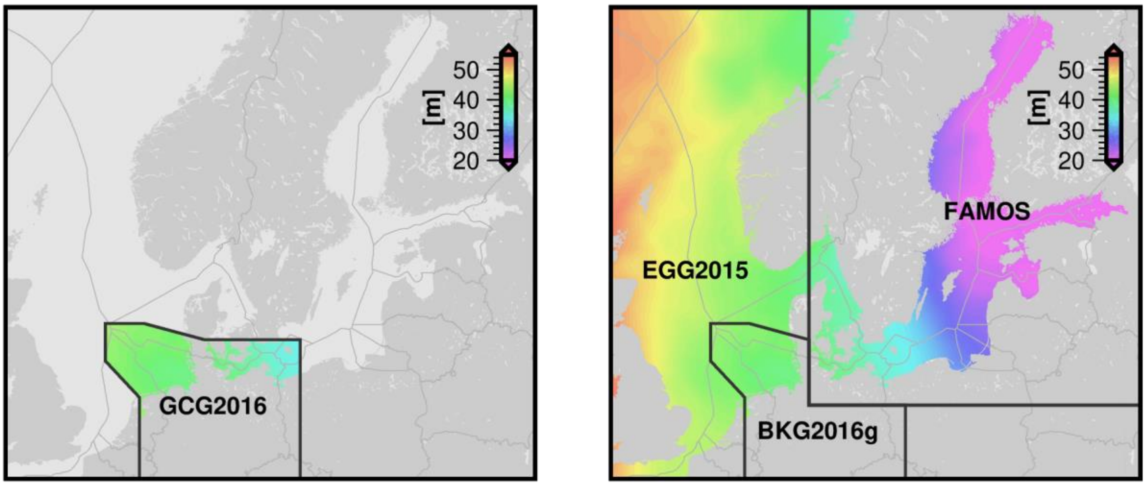


Figure 2: Reference surfaces of the product variants and their respective ellipsoidal heigh above GRS80. Left: „gcg“ – official German height reference, Right: „grav“—gravimetric Geoid

The “gcg” (a) variant is the standard product for sea level in Germany. Potential areas of application include the planning of coastal protection measures, surveying work in coastal and offshore areas, ship navigation/nautical science, and similar fields. It is valid within the German Exclusive Economic Zone (EEZ). The heights refers to the German Combined Quasigeoid GCG2016 (in the updated version of 2023) – the official German elevation reference. The height reference surface for nautical navigation, the sea chart datum (SKN)[1], is defined in the

[1]BSH - Das deutsche Seekartennull (SKN)

German sector of the Baltic Sea by the BSCD2000^{DHHN2016} and is practically identical to the GCG2016. In the German sector of the North Sea, the quasigeoid height of the GCG2016 was additionally reduced by tidal effects (Lowest Astronomical Tide - LAT) when determining the SKN.

The “grav” variant (b) is specifically intended for scientific and cross-border applications (gravimetric geoid modeling). In oceanography, for example for calculating geostrophic velocities, a physical-gravimetric model of the height reference surface is more suitable. This is implemented in the “grav” variant by the gravimetric geoid models BKG2016g (purely gravimetric model of GCG2016), FAMOS-Geoid (purely gravimetric model of BSCD2000) and EGG2015. The geoid models refer to the Amsterdam water level (NAP), have been transformed into the mean-tide system of permanent tides to match the observations of satellite altimetry and have been aligned with each other over a 30 km wide transition zone.

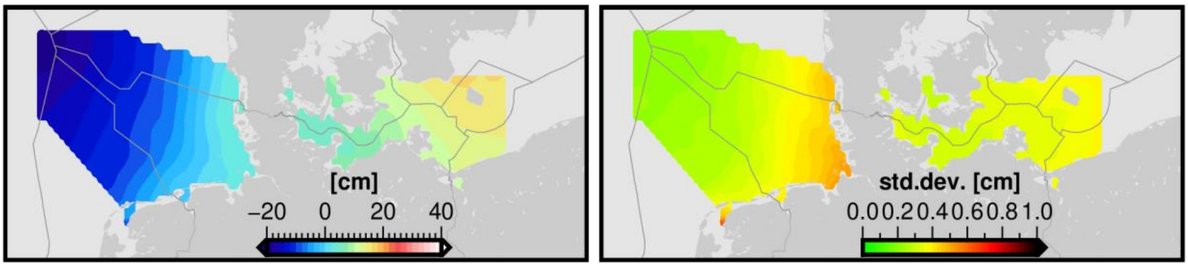


Figure 3: Mean sea surface height above the official German height reference surface GSC2016 („gcg“) and corresponding accuracy (standard deviation)

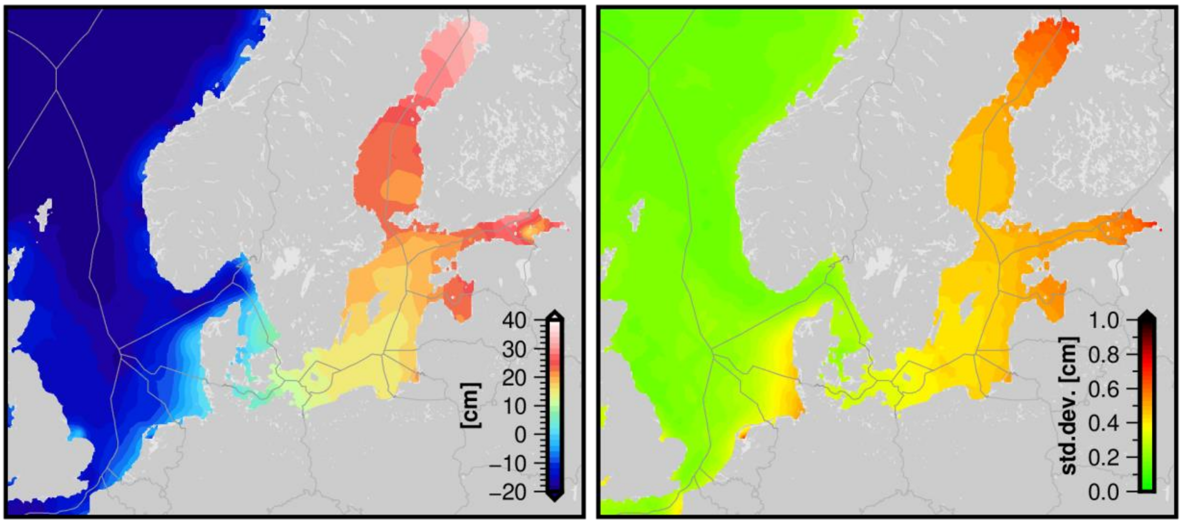


Figure 4: Mean sea surface height above the gravimetric geoid („grav“) and corresponding accuracy (standard deviation)

2.1.2 Data format

NetCDF

- common scientific binary data format
- all parameters in one file, readable e.g. witht ncdump, ncview, Panoply, QGIS etc.
- format description via `ncdump -h mean_sea_level.grav.nc`:

```
dimensions:
	lat = 181 ;
	lon = 241 ;
variables:
	char crs ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:long_name = "CRS definition" ;
		crs:longitude_of_prime_meridian = 0. ;
		crs:semi_major_axis = 6378137. ;
		crs:inverse_flattening = 298.257223563 ;
	float lat(lat) ;
		lat:standard_name = "latitude" ;
		lat:long_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:actual_range = 48.f, 66.f ;
	float lon(lon) ;
		lon:standard_name = "longitude" ;
		lon:long_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:actual_range = -5.f, 31.f ;
	float mdt_grav(lat, lon) ;
		mdt_grav:grid_mapping = "crs" ;
		mdt_grav:long_name = "mean dynamic topography above gravimetric geoid" ;
		mdt_grav:unit = "m" ;
		mdt_grav:year_ref = 2008.45081967213 ;
		mdt_grav:year_range = 1992.79508196721, 2025.81369863014 ;
	float mdt_grav_std(lat, lon) ;
		mdt_grav_std:grid_mapping = "crs" ;
		mdt_grav_std:long_name = "standard deviation of mean dynamic topography above gravimetric geoid" ;
		mdt_grav_std:unit = "m" ;
		mdt_grav_std:year_ref = 2008.45081967213 ;
		mdt_grav_std:year_range = 1992.79508196721, 2025.81369863014 ;
// global attributes:
		:Conventions = "CF-1.6" ;
```

GeoTiff

- widely used raster data format for GIS applications
- one file per parameter (mdt_grav, mdt_grav_std, mdt_gcg ,mdt_gcg_std)
- no metadata in files themselves but to NetCDF

2.1.3 Data basis satellite altimetry

The sea level products were derived from observations made by altimeter satellites since 1992. The satellite missions were and are operated by various organizations such as ESA[2], NASA[3], CNES[4], and others. The RADS (Radar Altimeter Database System, Scharroo et al. 2013[5]) collects data from the various satellite operators and makes it available in a uniform format (see Figure 5). This data forms the basis for altimetry analysis at the BKG.

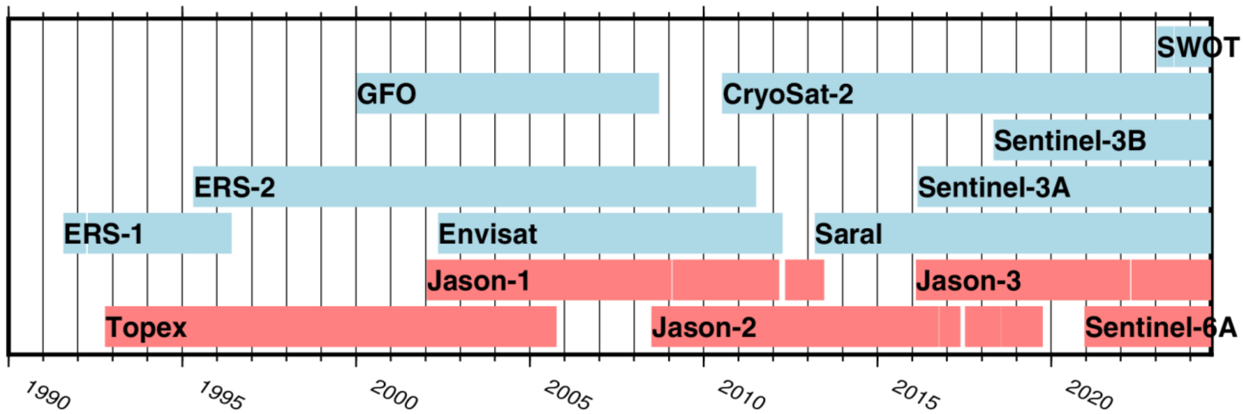


Figure 5: Observation periods of the satellite missions used. The reference missions (red) ensure continuous observations along the reference tracks. Additional missions (blue) supplement this data and improve spatial and temporal coverage.

BKG uses data from RADS and supplements this global dataset with the following regional models and data for the North Sea and Baltic Sea:

- New tidal model FES2022, which is particularly notable for its regional improvements in coastal areas
- Regional geoid models and comparable reference surfaces
    - GCG2016v2023 / BKG2016g geoid
    - BSCD2000 / FAMOS geoid
    - EGG2015
- Regional altimeter calibration:
    - Relative calibration of reference missions based on quasi-simultaneous observations during the tandem phases of the missions
    - Relative calibration of additional missions based on crossover points with the reference missions
    - Absolute calibration based on the Helgoland and FINO-2 offshore tide gauges

[2] European Space Agency
[3] National Aeronautics and Space Administration, USA
[4] Centre national d'études spatiales, Frankreich
[5] Scharroo, R., E. W. Leuliette, J. L. Lillibridge, D. Byrne, M. C. Naeije, and G. T. Mitchum, RADS: Consistent multi-mission products, in *Proc. of the Symposium on 20 Years of Progress in Radar Altimetry, Venice, 20-28 September 2012,* Eur. Space Agency Spec. Publ., ESA SP-710, p. 4 pp., 2013.

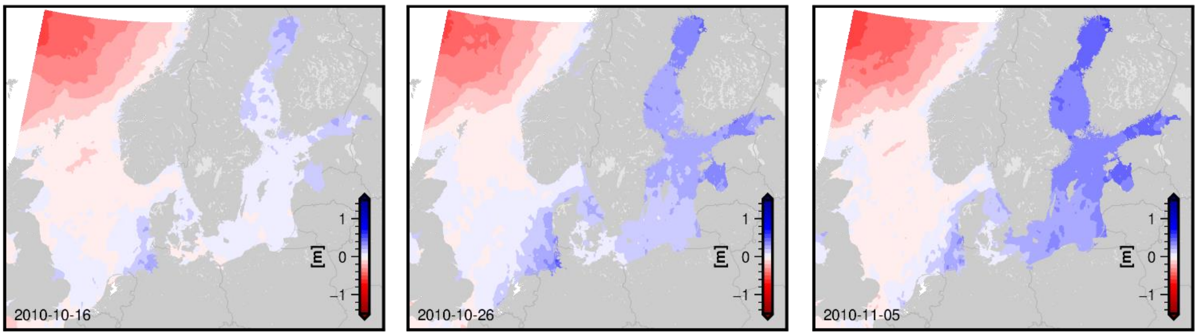


Figure 6: Examples of grids showing the average water level for three consecutive 10-day periods

The local mean water level was calculated from altimetric height measurements with a spatial resolution of approximately 10 km and a temporal resolution of 10 days (Figure 6). A Gaussian filter was used for this purpose (spatial sigma 40 km, temporal sigma 5 days). Higher-frequency sea level variations due to tides and weather influences were corrected in advance using models.

The mean sea level and its temporal change were then determined from the time series of each grid cell in a parameter estimation. The estimation parameters include a mean reference height at a specified reference time, a local trend in sea level changes, and typical seasonal fluctuations. The mean reference heights correspond to the product of the mean sea level. The epoch 2008.45 was chosen as the reference time. This epoch corresponds to the mean observation epoch of the DHHN2016 and is also very close to the middle of the altimeter period, so that sea level changes have a minimal influence here. The product “Time series of sea surface height in the North and Baltic Sea” (or the trends contained therein) can be used to correct temporal changes to other epochs.

3 Further Information

Further information concerning the product are available at gdz.bkg.bund.de. In case of any questions, you are welcome to contact our service centre at dlz@bkg.bund.de.

General information regarding the Federal Agency for Cartography and Geodesy can be found on our homepage www.bkg.bund.de.