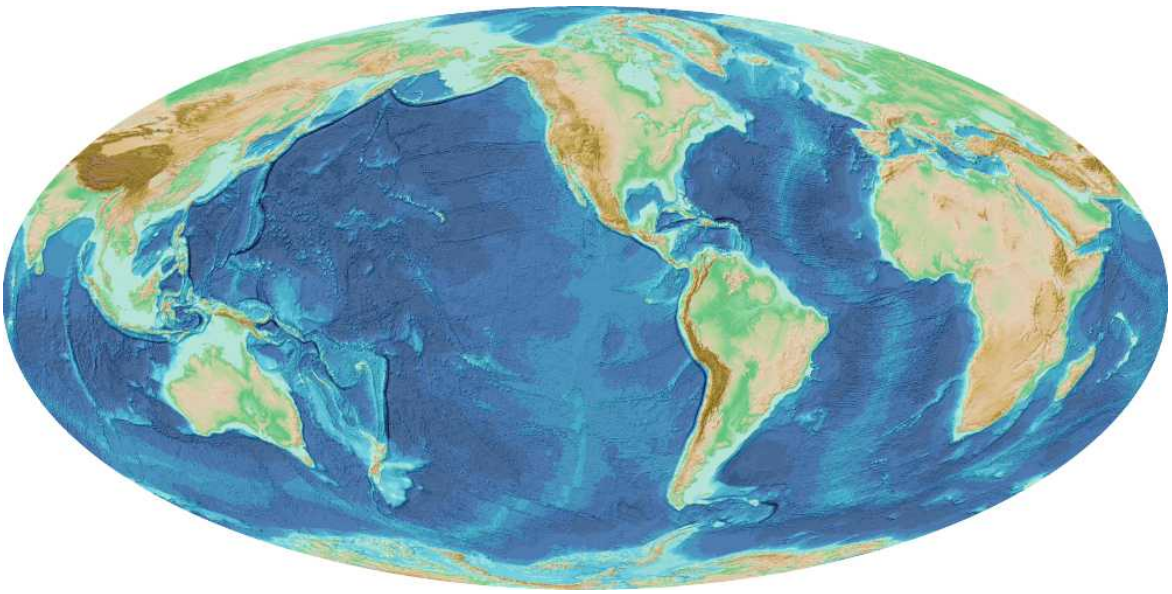
GEBCO's global gridded bathymetric data sets



1 Introduction

This documentation provides information on GEBCO's global bathymetric grids developed since 2019, through the Nippon Foundation-GEBCO Seabed 2030 Project. This is a collaborative project between the Nippon Foundation of Japan and GEBCO. The Seabed 2030 Project aims to bring together all available bathymetric data to produce the definitive map of the world ocean floor and make it available to all.

The Nippon Foundation is a non-profit philanthropic organisation active around the world. GEBCO is an international group of mapping experts developing a range of bathymetric data sets and data products, operating under the joint auspices of the International Hydrographic Organization (IHO) and UNESCO's Intergovernmental Oceanographic Commission (IOC).

The latest GEBCO grid, GEBCO_2021, was published in July 2021 and is a global terrain model for ocean and land, providing elevation data, in meters, on a 15 arc-second interval grid.

GEBCO's grids are available to download according to the Terms of Use provided in Section 7 below.

1.1 Seabed 2030 Data Center structure

Since 2019, GEBCO's global grids have been developed, on behalf of GEBCO, by the Seabed 2030 Data Centers, comprised of four Regional Centers and a Global Center.

The Regional Centers are responsible for championing mapping activities; assembling and compiling bathymetric information and collaborating with existing mapping initiatives in their regions. The Global Center is responsible for producing and delivering centralized GEBCO products, such as bathymetric grids.

1.2 Seabed 2030 Centers

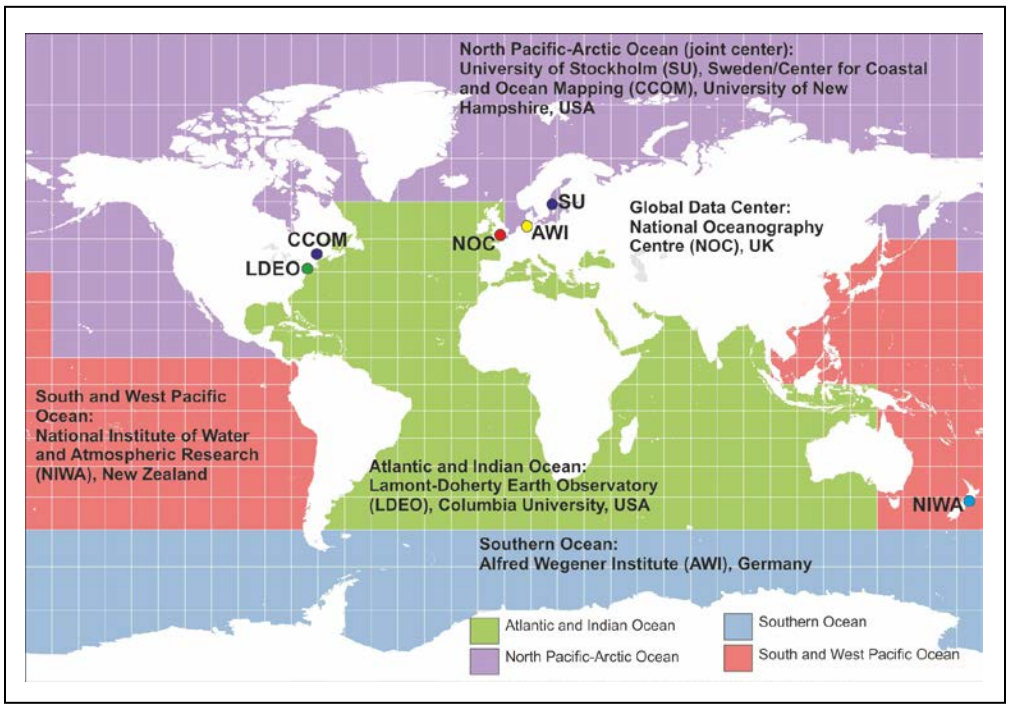


Figure 1. Locations of the Seabed 2030 Centers

- Southern Ocean - hosted at the Alfred Wegener Institute (AWI), Germany
- South and West Pacific Ocean - hosted at the National Institute of Water and Atmospheric Research (NIWA), New Zealand
- Atlantic and Indian Oceans - hosted at the Lamont Doherty Earth Observatory (LDEO), Columbia University, USA
- Arctic and North Pacific Oceans - hosted at Stockholm University (SU), Sweden and the Center for Coastal and Ocean Mapping at the University of New Hampshire (UNH), USA
- Global Data Center - hosted at the British Oceanographic Data Centre (BODC), National Oceanography Centre (NOC), UK

2 Grid development

GEBCO's global grids are continuous terrain models for ocean and land with a spatial resolution of 15 arc seconds. The data values are pixel-centre registered i.e. they refer to elevations, in meters, at the centre of grid cells.

Below, information is given about the generation of the GEBCO_2021, GEBCO_2020 and GEBCO_2019 Grids.

2.1 GEBCO_2021

The GEBCO_2021 Grid was released in July 2021. It uses as a 'base' Version 2.2 of the SRTM15+ data set between latitudes of 50° South and 60° North. This data set is a fusion of land topography with measured and estimated seafloor topography. This version of SRTM15+ is similar to version 2.1 [Tozer et al., 2019] with minor updates. Version 2.2 uses

predicted depths based on the V29 gravity model [Sandwell et al., 2019] and approximately 400 small areas containing suspect data were visually identified and removed from the grid.

The SRTM15+ base grid has been augmented with the gridded bathymetric data sets developed by the four Seabed 2030 Regional Centers to produce the GEBCO_2021 Grid.

The Regional Centers have compiled gridded bathymetric data sets, largely based on multibeam data, for their areas of responsibility. These regional grids were then provided to the Global Center.

For areas outside of the polar regions (primarily south of 60°N and north of 50°S), these data sets are in the form of 'sparse grids', i.e. only grid cells that contain data were populated. For the polar regions, complete grids were provided due to the complexities of incorporating data held in polar coordinates.

The compilation of the GEBCO_2021 Grid from these regional data grids was carried out at the Global Center, with the aim of producing a seamless global terrain model.

The data sets provided as sparse grids by the Regional Centers were included on to the base grid without any blending, i.e. grid cells in the base grid were replaced with data from the sparse grids. This was with the aim of avoiding creating edge effects, 'ridges and ripples', at the boundaries between the sparse grids and base grid during the blending process used previously. In addition, this allows a clear identification of the data source within the grid, with no cells being 'blended' values. Routines from the Generic Mapping Tools (GMT) system were used to do the merging of the data sets.

For the polar data sets, and the adjoining North Sea area, supplied in the form of complete grids these data sets were included using feather blending techniques from GlobalMapper software version 11.0 made available by Blue Marble Geographics.

Some additional edits were made to the final grid to remove erroneous values identified in the previous grid and notified to the Global Centre.

The GEBCO_2021 Grid includes data sets from a number of international and national data repositories and regional mapping initiatives. Information on the data sets included in the grid is given in our data contributors list.

Ice-surface elevation and under-ice topography

The primary GEBCO_2021 grid contains land and ice surface elevation information - as provided for previous GEBCO grid releases. In addition, for the 2021 release a version of the grid is available with under-ice topography information for Greenland and Antarctica.

The information for ice-surface elevation and under-ice topography/bathymetry is taken from IceBridge BedMachine Greenland, Version 3 (Morlighem, M. et al. 2017) and data based on MEaSUREs BedMachine Antarctica, Version 2 (Morlighem, M. et al 2020).

Land Data

The land data in the GEBCO_2021 Grid are taken directly from SRTM15+ V2.2 data set for all areas outside the Polar regions – see the SRTM15_plus data set documentation for more information.

South of 60°S, the land/ ice-surface elevation topography is largely determined from MEaSUREs BedMachine Antarctica, Version 2 (Morlighem, M. et al 2020). For areas north of 60°N, land data are largely taken from the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) data set (Danielson, J.J., and Gesch, D.B., 2011).

2.2 GEBCO_2020

The GEBCO_2020 Grid was released in May 2020. It uses as a 'base' Version 2 of the SRTM15+ data set (Tozer et al, 2019). This data set is a fusion of land topography with measured and estimated seafloor topography. It is augmented with the gridded bathymetric data sets developed by the four Seabed 2030 Regional Centers.

The Regional Centers have compiled gridded bathymetric data sets, largely based on multibeam data, for their areas of responsibility. These regional grids were then provided to the Global Center.

For areas outside of the polar regions (primarily south of 60°N and north of 50°S), these data sets are in the form of 'sparse grids', i.e. only grid cells that contain data were populated. For the polar regions, complete grids were provided due to the complexities of incorporating data held in polar coordinates.

The compilation of the GEBCO_2020 Grid from these regional data grids was carried out at the Global Center, with the aim of producing a seamless global terrain model.

In contrast to the development of the previous GEBCO grid, GEBCO_2019, the data sets provided as sparse grids by the Regional Centers were included on to the base grid without any blending, i.e. grid cells in the base grid were replaced with data from the sparse grids. This was with the aim of avoiding creating edge effects, 'ridges and ripples', at the boundaries between the sparse grids and base grid during the blending process used previously. In addition, this allows a clear identification of the data source within the grid, with no cells being 'blended' values. Routines from Generic Mapping Tools (GMT) system were used to do the merging of the data sets.

For the polar data sets, and the adjoining North Sea area, supplied in the form of complete grids these data sets were included using feather blending techniques from GlobalMapper software version 11.0 made available by Blue Marble Geographic.

Some additional edits were made to the final grid to remove erroneous values identified in the previous grid and notified to the Global Centre.

The GEBCO_2020 Grid includes data sets from a number of international and national data repositories and regional mapping initiatives. Access a list of the data sets included in the GEBCO_2020 Grid.

Land Data

The land data in the GEBCO Grid are taken directly from SRTM15+ V2 data set for all areas outside the Polar regions.

South of 60°S, the land topography is largely determined from Bedmap2 (Fretwell et al, 2013). For areas north of 60°N, land data are taken from the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) data set.

2.3 GEBCO_2019

The GEBCO_2019 Grid was released in April 2019. It uses as a 'base' Version 1 of the SRTM15+ data set (Olson et al, 2014). This data set is a fusion of land topography with measured and estimated seafloor topography. It is largely based on version 11 of SRTM30+ (Becker et al, 2009; Sandwell et al, 2014), augmented with the gridded bathymetric data sets developed by the four Seabed 2030 Regional Centers. The published data were recalculated on a cell-registered grid for use by GEBCO.

The Seabed 2030 Regional Centers have compiled gridded bathymetric data sets, largely based on multibeam data, on a sub-set of the global grid for their areas of responsibility. These regional grids were then provided to the Global Center. For areas outside of the polar regions (primarily south of 60N and north of 50S), these data sets are in the form of 'sparse grids', i.e. only grid cells that contain data were populated. For the polar regions, complete grids were provided due to the complexities of incorporating data held in polar coordinates.

The compilation of the GEBCO_2019 Grid from these regional data grids, with some additional source data sets, was carried out at the Global Center, with the aim of producing a seamless global terrain model.

The majority of the work, for the non-polar regions, was done using the 'remove-restore' procedure (Smith and Sandwell, 1997; Becker, Sandwell and Smith, 2009 and Hell and Jakobsson, 2011). This is a two stage process of computing the difference between the new data and the 'base' grid, gridding the difference and adding this difference back to the existing 'base' grid. The aim is to achieve a smooth transition between the 'new' and 'base' data sets with the minimum of perturbation of the existing base data set.

For the polar data sets, and the adjoining North Sea are, supplied in the form of complete grids these data sets were included using feather blending techniques from GlobalMapper software version 11.0, made available by Blue Marble Geographic.

The GEBCO_2019 Grid includes data sets from a number of international and national data repositories and regional mapping initiatives. Access information on the data sets included in the GEBCO_2019 Grid.

Land Data

The land data in the GEBCO Grid are taken directly from SRTM15+ for all areas outside the Polar regions.

South of 60°S, the land topography is determined from Bedmap2 (Fretwell et al, 2013).

3. GEBCO Type Identifier (TID) Grid

GEBCO's bathymetric grids are accompanied by a Type Identifier (TID) grid. This data set identifies the type of source data that the corresponding grid cells in the GEBCO Grid are based on.

The table below details the coding of the GEBCO Type Identifier (TID) grid.

TID	Definition
0	Land
Direct measurements	
10	Singlebeam - depth value collected by a single beam echo-sounder
11	Multibeam - depth value collected by a multibeam echo-sounder
12	Seismic - depth value collected by seismic methods
13	Isolated sounding - depth value that is not part of a regular survey or trackline
14	ENC sounding - depth value extracted from an Electronic Navigation Chart (ENC)

15	Lidar - depth derived from a bathymetric lidar sensor
16	Depth measured by optical light sensor
17	Combination of direct measurement methods
Indirect measurements	
40	Predicted based on satellite-derived gravity data - depth value is an interpolated value guided by satellite-derived gravity data
41	Interpolated based on a computer algorithm - depth value is an interpolated value based on a computer algorithm (e.g. Generic Mapping Tools)
42	Digital bathymetric contours from charts - depth value taken from a bathymetric contour data set
43	Digital bathymetric contours from ENCs - depth value taken from bathymetric contours from an Electronic Navigation Chart (ENC)
44	Bathymetric sounding - depth value at this location is constrained by bathymetric sounding(s) within a gridded data set where interpolation between sounding points is guided by satellite-derived gravity data
45	Predicted based on helicopter/flight-derived gravity data
46	Depth estimated by calculating the draft of a grounded iceberg using satellite-derived freeboard measurement.
Unknown	
70	Pre-generated grid - depth value is taken from a pre-generated grid that is based on mixed source data types, e.g. single beam, multibeam, interpolation etc.
71	Unknown source - depth value from an unknown source
72	Steering points - depth value used to constrain the grid in areas of poor data coverage

4. GEBCO Grid, Vertical and horizontal datum

GEBCO's global gridded data sets provide coverage, spanning 89° 59' 52.5"N, 179° 59' 52.5"W to 89° 59' 52.5"S, 179° 59' 52.5"E on a 15 arc-second geographic latitude and longitude grid.

Each grid consists of 43200 rows x 86400 columns, giving 3,732,480,000 data points. The data values are pixel-centre registered i.e. they refer to elevations, in meters, at the centre of grid cells.

The GEBCO grid can be assumed to be relative to WGS84.

GEBCO's global elevation models are generated by the assimilation of heterogeneous data types, assuming all of them to be referred to Mean Sea Level. However, in some shallow water areas, the grid includes data from sources having a vertical datum other than mean sea level.

5. Data Dissemination

GEBCO's gridded data sets are made available in a number of different formats as described in the following sections.

Data for the GEBCO_2021 Grid are available in each format as a 'one-click' download option from https://www.gebco.net/data_and_products/gridded_bathymetry_data/

Data for the global GEBCO_2020 and GEBCO_2019 Grids are available in netCDF format from https://www.gebco.net/data_and_products/historical_data_sets/.

User-defined subsets from all three grids can also be downloaded in various formats using the download tool. The information below details the formats available for data sets accessed through the download tool.

5.1 CF-compliant NetCDF format

NetCDF (Network Common Data Form) is a self-describing, platform independent data format.

GEBCO's global grids of elevation values are available in NetCDF 4 format and conform to the NetCDF Climate and Forecast (CF) Metadata Convention v1.6 (http://cfconventions.org/).

Within the NetCDF files, the data are stored as a two-dimensional array of 2-byte integer values of elevation in metres, with negative values for bathymetric depths and positive values for topographic heights.

GEBCO's TID grids are provided in the same NetCDF format, but data are stored as a two-dimensional array of single byte integers.

- The global GEBCO_2021 bathymetric dataset is provided as a single 7.5 GB file.
- The global GEBCO_2021 TID grid is provided as a single 4 GB file

5.2 Esri ASCII raster format

This is an ASCII format developed for the export/exchange of Esri ARC/INFO rasters. The format consists of a header that gives the geographic extent and grid interval of the data set, followed by the actual grid cell data values.

5.3 Data GeoTIFF

The GeoTiff format contains geo-referencing (geographic extent and projection) information embedded within a Tiff file.

6. Data set attribution

If the data sets are used in a presentation or publication then we ask that you acknowledge the source. This should be of the form:

GEBCO_2021 Grid

GEBCO Compilation Group (2021) GEBCO 2021 Grid (doi:10.5285/c6612cbe-50b3-0cff-e053-6c86abc09f8f)

GEBCO_2020 Grid

GEBCO Compilation Group (2020) GEBCO 2020 Grid (doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9)

GEBCO_2019 Grid

GEBCO Compilation Group (2019) GEBCO 2019 Grid (doi:10.5285/836f016a-33be-6ddc-e053-6c86abc0788e)

7. Terms of use and disclaimer

7.1 Scope

- These terms of use apply to The GEBCO Grid and other GEBCO-derived information products
- For brevity 'The GEBCO Grid' is used throughout and should be interpreted as meaning The GEBCO Grid and other GEBCO-derived information products
- Bathymetric Data refers to measurements made by various instruments of the ocean depth, associated ocean properties and the supporting metadata
- Information products are the result of applying algorithms, mathematical techniques, scientific theory and Intellectual Property to data to create useful, derived values.
- As the GEBCO Grid is created by interpolating, applying algorithms and mathematical techniques to bathymetric data, GEBCO considers the GEBCO Grid to be an information product
- GEBCO does not provide the underlying source bathymetric data when distributing the GEBCO Grid

7.2 Terms of use

The GEBCO Grid is placed in the public domain and may be used free of charge.

Use of the GEBCO Grid indicates that the user accepts the conditions of use and disclaimer information given below.

Users are free to:

- Copy, publish, distribute and transmit The GEBCO Grid
- Adapt The GEBCO Grid
- Commercially exploit The GEBCO Grid, by, for example, combining it with other information, or by including it in their own product or application

Users must:

- Acknowledge the source of The GEBCO Grid. A suitable form of attribution is given in the documentation that accompanies The GEBCO Grid.
- Not use The GEBCO Grid in a way that suggests any official status or that GEBCO, or the IHO or IOC, endorses any particular application of The GEBCO Grid.
- Not mislead others or misrepresent The GEBCO Grid or its source.

7.3 Disclaimer

- The GEBCO Grid should NOT be used for navigation or for any other purpose involving safety at sea.

- The GEBCO Grid is made available 'as is'. While every effort has been made to ensure reliability within the limits of present knowledge, the accuracy and completeness of The GEBCO Grid cannot be guaranteed. No responsibility can be accepted by GEBCO, IHO, IOC, or those involved in its creation or publication for any consequential loss, injury or damage arising from its use or for determining the fitness of The GEBCO Grid for any particular use.
- The GEBCO Grid is based on bathymetric data from many different sources of varying quality and coverage.
- As The GEBCO Grid is an information product created by interpolation of measured data, the resolution of The GEBCO Grid may be significantly different to that of the resolution of the underlying measured data.

8.0 Reporting bugs in the GEBCO Grid

While every effort is made to produce an error free grid, some artefacts may still appear in the data set. Please see our errata web page for information on known errors in the dataset.

If you find any anomalies in the grid then please report them via email (gdacc@seabed2030.org), giving the problem location, and we will investigate.

9. References

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