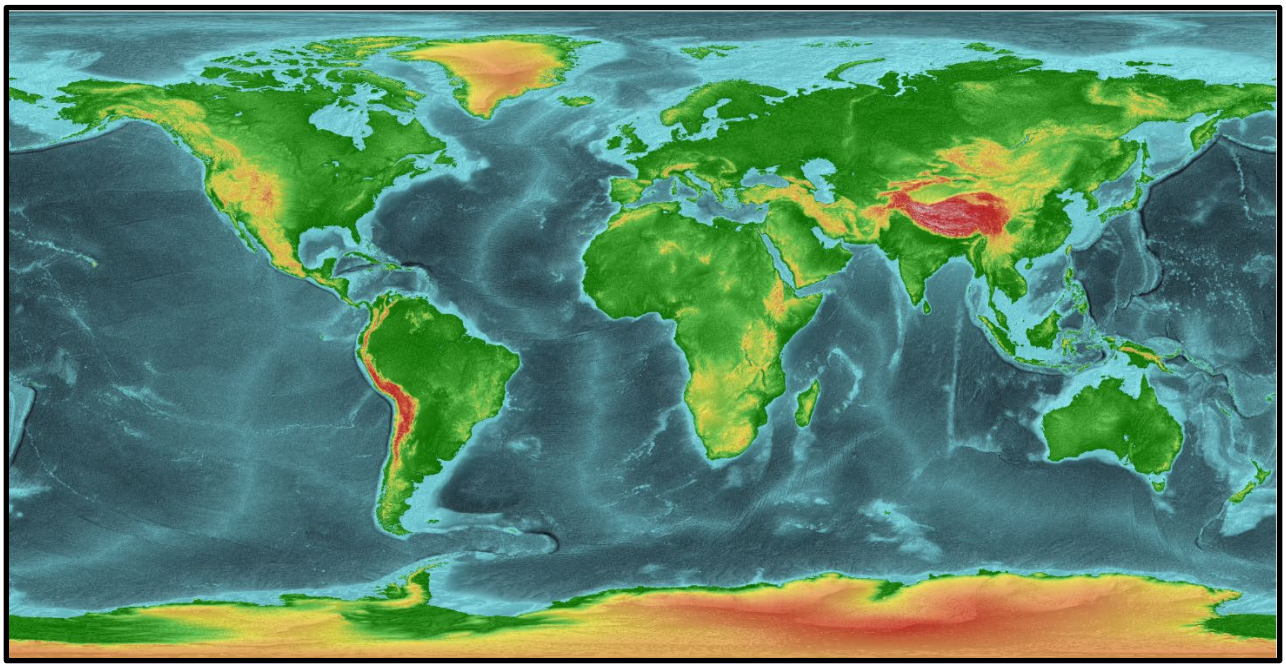
ETOPO 2022

User Guide



National Centers for Environmental Information

1. Intent of this Document and POC

1.1 This document is intended to provide a basic understanding of the product (or dataset) including points of contact, sources used to develop the product, quality control practices, and steps taken to validate the accuracy of the product. References are provided at the end of this document for users interested in further technical details.

1.2 Technical point of contact for this dataset:

Michael MacFerrin (michael.macferrin@noaa.gov) (primary developer)

Matthew Love (matthew.love@noaa.gov) (co-developer)

Christopher Amante (christopher.amante@noaa.gov) (project manager)

2. Product Overview and Intended Uses

2.1 ETOPO 2022 Overview

ETOPO 2022 is a release of NOAA's "Earth TOPOgraphy" dataset. It is a full-coverage, seamless, gridded topographic and bathymetric bare-earth elevation dataset. Primary end-users of ETOPO are coastal hazard and tsunami modelers; however, ETOPO is used as a baseline dataset in thousands of scientific papers, data products, and references worldwide. ETOPO 2022 is an updated, higher-resolution version of previously released ETOPO5 (5 arc-minute), ETOPO2 (2'), and ETOPO1 (1') global grids. For further use in this document, "ETOPO" refers to the ETOPO 2022 release.

ETOPO is released globally as a full-global-coverage earth surface elevation file comprised of 288 individual 15x15 degree tiles (latitude/longitude) at 15-arc-second geographic resolution. The tiles are provided in GeoTiff and Network Common Data Form (NetCDF) formats, with identical information provided in each format. An additional 62 tiles have "bed" versions that provide bedrock elevations under the surface of the Greenland and Antarctic ice sheets. Each 15s tile has a Source ID (SID) integer file identifying from which data source each ETOPO grid cell was acquired. All tiles are in horizontal WGS84 geographic coordinates (EPSG[1]:4326) and referenced in meters relative to the Earth Gravitational Model of 2008 (EGM2008) geoid surface (EPSG:3855). Each tile comes with an accompanying integer Source ID ("sid") tile specifying from which source dataset each ETOPO elevation was derived (see Section 5). Data Sources and Processing), as well as an accompanying "geoid" tile for converting EGM2008 geoid heights into WGS84 ellipsoid elevation heights (EPSG:4979). Since most other geoid, ellipsoid, and/or tidal vertical datums are defined by grids in reference to the WGS84 ellipsoid, this eases the conversion of ETOPO 2022 tiles into other vertical reference datums of the user's choice. For most purposes, EGM2008 is an adequate approximation of mean sea level.

[1] EPSG = European Petroleum Survey Group, commonly-used codes for horizontal and vertical coordinate reference systems. References available at https://epsg.io/.

2.2 Elevation Conversion

To convert a given tile from EGM2008 to WGS84-referenced elevations, add the values of the elevation tile to the geoid-height tile:

ETOPO Elevation (EGM2008) + GEOID = WGS84 Elevation

Single global tiles are provided at 30- and 60-arc-second (i.e., 1-arc-minute) resolutions in both GeoTiff and NetCDF format, in surface and ice-sheet-bed versions. 30- and 60-second grids were downsampled from the 15-arc-second elevation tiles for more general uses, and do not have accompanying SID tiles.

2.3 Naming Convention

ETOPO 2022 tiles are named in the following manner:

ETOPO_2022_v[#]_[RR]s_[N][YY][W][XXX][_suffix][.tif]

with the following information in place of the brackets []:

[#] - Version number of the release. In this case, version 1.

[RR] - Data tile resolution (1, 15, 30, 60), in arc-seconds

[N] - “N” or “S”, for Northern or Southern hemisphere

[YY] - 2-digit latitude of tile’s northern (top) border

[W] - “W” or “E”, for Eastern or Western hemisphere

[XXX] - 3-digit longitude of the tile’s western (left) border

[_suffix] - “_surface”: surface elevations; “_bed”: bed elevations, “_sid”: source id numbers, “_geoid”: geoid heights.

[.tif] - File extension: .tif (GeoTiff) or .nc (NetCDF) formats.

For example, a tile named

ETOPO_2022_v1_15s_N60W045_bed.tif

is a 15-arc-second resolution GeoTiff file with a North-West (upper-left) corner at North 60-degrees latitude and West 45-degrees longitude, in this case containing bedrock elevations under the surface of the Greenland and Antarctic ice sheets (with ground surface elevations elsewhere in the tile).

All ETOPO tiles have a nodata value of -99,999, although this value is not in any ETOPO grids.

3. Data Field Description

Data Field	Description
Variable names and units in product	- Elevation - Source ID
Spatial resolution	15 arc-seconds longitude & latitude (WGS84 coordinates)
Temporal resolution and extent	Data collected from various sources (see Data Sources and Processing)
Coverage	Global (-180 to 180 longitude, -90 to 90 latitude)

4. Dataset Usage and Citation

ETOPO tiles are freely available to use for all private, academic, or commercial purposes. Data is available for download on the NOAA ETOPO landing page.

To reference the ETOPO 2022 document, please cite the following:

NOAA National Centers for Environmental Information. 2022: ETOPO 2022 15 Arc-Second Global Relief Model. NOAA National Centers for Environmental Information. https://doi.org/10.25921/fd45-gt74 . Accessed [date].

ETOPO 2022 metadata may be accessed here: ETOPO 2022 metadata landing page

5. Data Sources and Processing

ETOPO Source datasets. Each of these datasets contributed elevation data used in the ETOPO product. (Other data sources were assessed and evaluated but were not included in the final ETOPO data product.)

Source Name	Vertical datum	Layer source id	Creator	Link[2]	Primary Use
GEBCO[3] 2022	MSL[4]	1	GEBCO Compilation Group (2022)	GEBCO 2022	Sea bathymetry base layer, large lake bathy
GEBCO 2022 sub-ice	MSL	2	GEBCO Compilation Group (2022)	GEBCO 2022	Sea bathymetry (sub-ice, polar regions)
NOAA[5] Estuarine DEMs	various	3	NOAA / NCEI[6] (archived)	NOAA Estuarine DEMs	Sea bathymetry
NOAA Regional DEMs	various	4	NOAA / NCEI (archived)	NOAA Regional DEMs Catalog	Sea bathymetry
GMRT[7] v4.0	MSL	5	GMRT.org, Lamont-Doherty Earth Observatory	GMRT Image Server	Sea bathymetry
BlueTopo	NAVD88[8]	6	NOAA OCS[9]	NOAA OCS AWS[10]	Sea bathymetry
BOEM[11] Gulf of Mexico Bathymetry	MSL	7	BOEM	BOEM GoM Deepwater Bathymetry	Gulf of Mexico bathymetry

[2] Website links are active at the time of creation of this document.
[3] GEBCO = General Bathymetric Chart of the Oceans
[4] Mean sea level
[5] National Oceanic and Atmospheric Administration
[6] National Centers for Environmental Information
[7] Global Multi-Resolution Topography
[8] North American Vertical Datum of 1988
[9] Office of the Coast Survey
[10] Amazon Web Services
[11] Bureau of Ocean Energy Management

Source Name	Vertical datum	Layer source id	Creator	Link[2]	Primary Use
ShallowBathy Everywhere	EGM2008	8	Oregon State University	ShallowBathy Everywhere	Sea bathymetry (select areas)
Copernicus DEM 30m	EGM2008	9	European Space Agency	Copernicus DEM 30m	Land topography
FABDEM[12]	EGM2008	10	European Space Agency and Bristol University	FABDEM Release Page	Land topography
BedMachine	EIGEN-6C4[13] geoid	11	NASA[14]	NSIDC[15] BedMachine Antarctica v2 and Greenland v4	Ice sheet bed topography
GEBCO Lake Depths	MSL	12	GEBCO Hydrolakes outlines and GEBCO elevations	GEBCO 2022	Global surveyed lake depths (very large lakes)
CUDEM[16]	various	13	NOAA / NCEI Coastal DEM Team	CUDEM 1/3-arc-sec and 1/9-arc sec catalogs[17]	Land topography and sea bathymetry (US & territories)

Other datasets were not directly included in ETOPO, but were instrumental for the development, production, and/or validation of the source data layers.

[12] Forest and Buildings Removed Copernicus DEM
[13] EIGEN-6G4 GOCE-derived gravity model
[14] National Aeronautics and Space Administration
[15] National Snow & Ice Data Center
[16] Continuously-Updated Digital Elevation Models
[17] Current released data tiles through August 2022

Source Name	Vertical datum	Creator	Link	Primary Use
ICESat-2 [18]	EGM2008 / WGS84[19]	NASA	NSIDC ATL03 v5, ATL08 v5	Photon elevation data for land DEM evaluation
HydroLakes	n/a	HydroSHEDS	HydroLakes release page	Global vector outlines of inland water bodies
OpenStreetMap	n/a	OpenStreetMap	OpenStreetMap web services	Building outlines (masked during ICESat-2 validation)

6. Quality Control

All source datasets are visually inspected for artifacts and obvious errors before being included in the ETOPO product. Ocean bathymetry data products are assessed based upon source resolution, quality, and age, and are ranked subjectively according to those metrics. (Since data sources such as GEBCO use a compilation of available ocean-depth soundings, it is often difficult to independently and quantitatively assess the accuracy of various bathymetric data sources).

Land surface datasets were ranked according to accuracy assessments as validated by NASA's ICESat-2 satellite, specifically ICESat-2 data collected during the calendar-year 2021 (1 January through 31 December). Datasets were assessed individually in their own native horizontal projections, and again in the final ETOPO product after horizontal regridding and vertical datum transformations. Details of ICESat-2 processing are outlined in the next section.

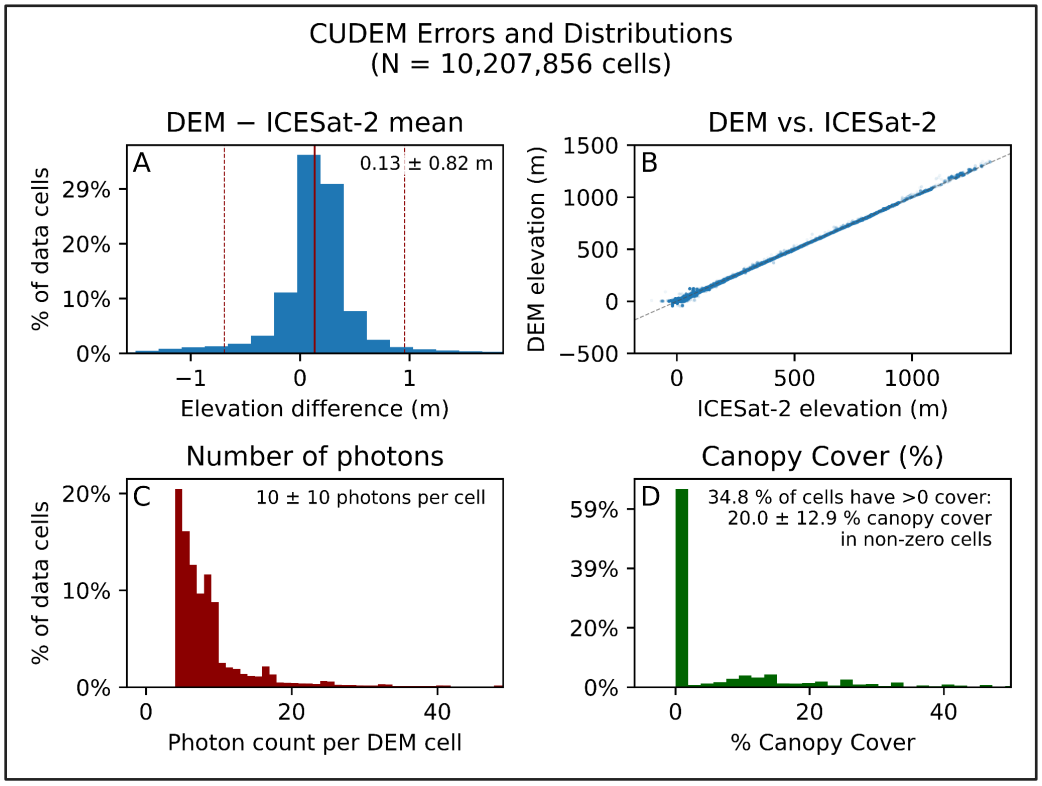
7. Validation

Land areas between 89S and 89N latitudes are evaluated for vertical accuracy using a database of 800-billion ICESat-2 ATL03 photons collected during the calendar year 2021. The ATL03 photon product is combined with adjoining ATL08 land-and-vegetation elevation granules to classify photons that are reflected off land or vegetation canopy. A land mask is produced using the Copernicus DEM dataset to filter out only solid-land areas, and the HydroLakes dataset is used to filter out photons reflecting off inland lakes and reservoirs (whose surface heights fluctuate frequently and are not reliable targets for validating land elevations). Since ETOPO 2022 is a bare-earth elevation dataset, photos that reflected off vegetation canopy (as classified in the ATL08 dataset) or building-tops (using the OpenStreetMap public web database) are filtered out. Remaining ground-reflecting photons are collected into each ETOPO grid cell where they fall. A mean of the interdecile range (10-90th percentile) of these photon elevations is used to

[18] Ice, Cloud, and Land Elevation Satellite-2

[19] World Geodetic Survey of 1984

produce an ICESat-2 derived ground elevation, which is subtracted from the ETOPO grid cell elevation to produce an error. Errors are compiled and assessed for each input layer (see Figure below for CUDEM topography assessments) and displayed (see Figure 1 below) as (A) a histogram, (B) 1:1 scatterplot with ICESat-2 elevations, (C) histogram of photon density per grid cell in the interdecile range, and (D) a histogram of average canopy cover over each grid cell.



The final vertical accuracy assessments for ETOPO 2022 are still being compiled with respect to ICESat-2 and will be made available in a revised version of this document.

8. References

Amante, C. and Eakins, B. A. (2009). ETOPO1 1 Arc-minute Global Relief Model: Procedures, Data Sources and Analysis, https://www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/docs/ETOPO1.pdf

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Shallow Bathymetry Everywhere: https://shallowbathymetryeverywhere.com/

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HydroLAKES - HydroSHEDS: https://www.hydrosheds.org/products/hydrolakes

OpenStreetMap: https://www.openstreetmap.org/

9. Dataset and Document Revision History

Rev 1.2 – 13 October 2022 - Citation information added.