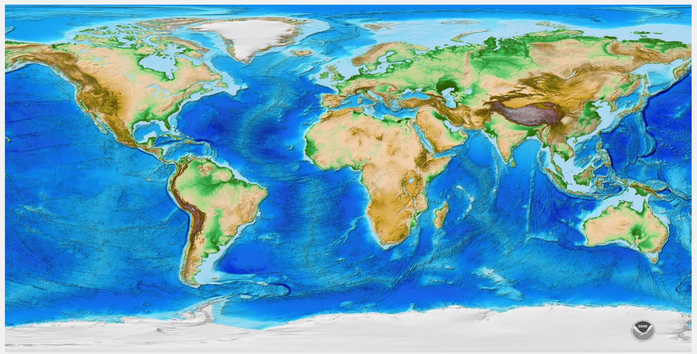
ETOPO 2022: An Updated NOAA Global Relief Model

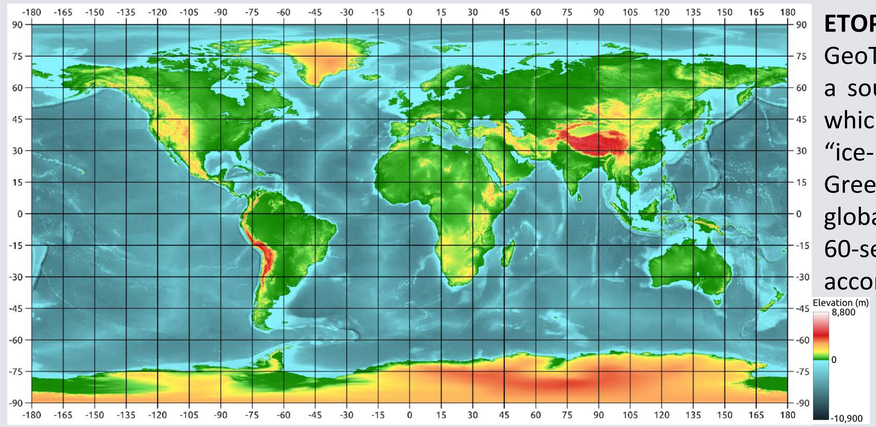
Michael MacFerrin[1], Christopher Amante[1], Kelly Carignan[1], Matthew Love[1], Elliot Lim[1], Kelly Stroker[2], Nic Arcos[2]
[1]Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder
[2]National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), Boulder, CO

Introduction



Here we announce the release (in October 2022) of the Earth TOPOgraphy (ETOPO 2022) dataset, from the National Oceanic & Atmospheric Administration's (NOAA's) National Centers for Environmental Information (NCEI). ETOPO 2022 is a **publicly-available**, **seamless**, **global** topo-bathy terrain elevation dataset at 15 arc-second spatial resolution. ETOPO's previous release, ETOPO1[1] (1 arc-minute) was used for years for tsunami propagation simulations, climate modeling, and other moderate-resolution scientific objectives. ETOPO 2022 combines multiple publicly-available land and ocean topography datasets, converts them to common grids and reference elevations, and uses data-assimilation, error-minimization, and validation techniques to produce the next generation seamless publicly-available global elevation for free public use.

ETOPO 2022 Product Description and Links



ETOPO 2022 is available as 288 15x15° tiles (left) in both GeoTiff and NetCDF formats. Accompanying each tile is a source-id tile to identify the individual sources from which a particular elevation was derived. 62 additional "ice-bed" topography tiles are available covering Greenland and Antarctic ice sheet bed elevations. Full-global tiles are available for download at 30-second and 60-second resolutions in GeoTiff or NetCDF, without accompanying source-id tiles.

Data and user guides are available for free download for any scientific, personal, or commercial use (excluding navigation). Data is available for direct download or through various data portals at:

https://www.ncei.noaa.gov/products/etopo-global-relief-model

Get the data!

Citation: 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].

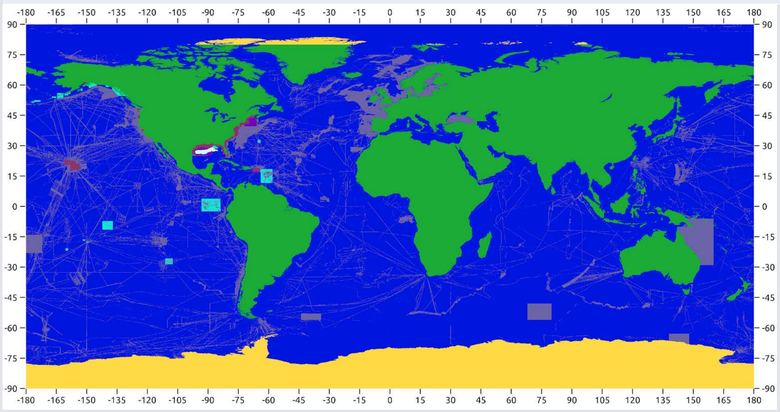
Datasets and Processing Summary

The following public elevation datasets are integrated into ETOPO 2022:

Land Topography	Ocean Bathymetry
Copernicus DEM[2]	NOAA Estuarine DEMs[6]
FABDEM[3] v1.0	NOAA Regional DEMs[7]
BedMachine Greenland[4] & Antarctica[5] (sub-ice) *(not shown below, used only in ice-bed product)*	GMRT[8] v4.0
	NOAA BlueTopo[9]
	BOEM[10] (Gulf of Mexico)
	ShallowBathy Everywhere[11]

Land and Ocean

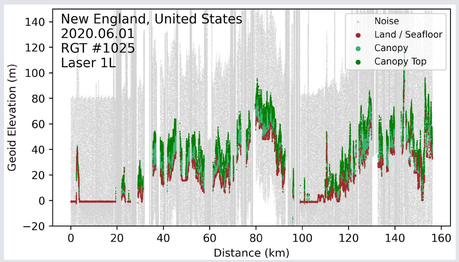
GEBCO[12] 2022 (ocean, land, and large lake bathymetry)
NOAA NCEI High-Res Coastal CUDEMs[13] (US + territories)



All source datasets are re-gridded to WGS84 lat/lon coordinates, converted to EGM2008 geoid heights, and cleaned as necessary to remove artifacts. Datasets are ranked and resampled into the ETOPO 2022 grid. Sources for the ice-surface grid are seen at left.

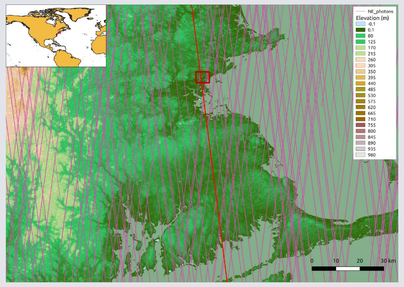
ETOPO 2022 Ice-surface sources. Color key in the table. Ice-bed product is identical except for areas surrounding Greenland & Antarctica, where BedMachine and GEBCO sub-ice topographies are used.

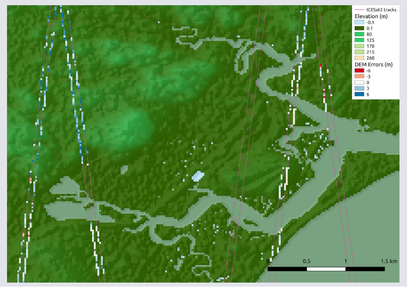
ICESat-2 Validation



Photon points from the Ice, Cloud, and land Elevation Satellite[14] 2 (ICESat-2) were used both to rank datasets as well as validate the ETOPO 2022 product over land. ICESat-2 photons from the calendar year 2021 were assimilated into a large database and used to assess the bare-earth elevations of land photons over grid-cells that underlie ICESat-2 orbit passes. A small number of ICESat-2 granules were discarded due to data artifacts. To validate bare-earth land only, a coastline mask was generated over each DEM tile to exclude grid cells that cover ocean (using the Copernicus DEM mask), inland water bodies (using the global HydroLakes dataset) and urban structures (using OpenStreetMap and the German Aerospace Service World Settlement Footprint datasets). To minimize biases due to spatial sampling, only grid-cells in which 45% or more of a grid-cell's area was "covered" (usually by multiple ICESat-2 orbits) were used in ETOPO accuracy assessments. Based on this good-coverage subset of grid cells, an initial validation of ETOPO 2022-15s shows an approximate RMSE of **3.78 m** compared to ICESat-2 photons.

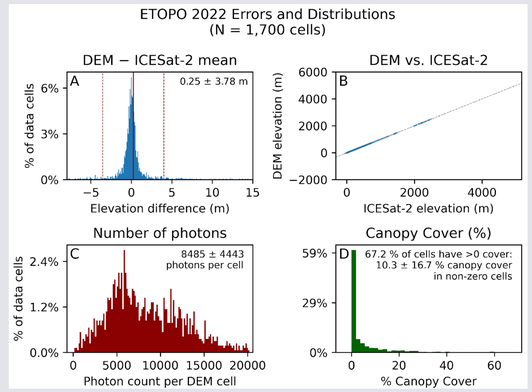
(Above) An ICESat-2 photon point cloud over New England, USA. Photons are filtered to identify canopy, canopy top, land, and noise. **(Below, left)** ICESat-2 orbit tracks over New England, USA. The track shown above is highlighted bold. The inset figure covers the area shown in below-center. **(Below, center)** ICESat-2 tracks over an inset of the New England coast. Here, a Copernicus DEM tile is being validated, with grid-cell level errors shown in the legend.





(Right) Distributions of ETOPO 2022 errors compared to ICESat-2 photons, specifically on the subset of grid-cells that contain 45% or more coverage measured using a sub-grid-cell coverage frame.

(Validation calculations are currently ongoing for ETOPO 2022. Final results may differ slightly from what is shown here.)



Future Work

ICESat-2 validations are currently being finished to comprehensively assess ETOPO 2022's accuracies worldwide. The ETOPO 2022 User Guide will be updated when those assessments are complete. Additionally, a set of regional coastal relief models (CRMs) are being produced at higher 1 arc-second resolutions over the US East Coast, Gulf Coast, Puerto Rico, and Hawaii where high-accuracy topo+bathy data are available.

This work is supported by NOAA through the Cooperative Agreement with CIRES, NA17OAR4320101.

References

1. Amante, C. & Eakins, B. A. **ETOPO 1** Arc-minute Global Relief Model: Procedures, Data Sources and Analysis. https://www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/docs/ETOPO1.pdf (2009).
2. The European Space Agency. **Copernicus DEM.** https://spacedata.copernicus.eu/web/cscda/dataset-details?articleId=394198.
3. Hawker, L. et al. A 30 m global map of elevation with forests and buildings removed. Environ. Res. Lett. 17, 024016 (2022).
4. Morlighem, M. et al. **BedMachine** v3: Complete Bed Topography and Ocean Bathymetry Mapping of Greenland From Multibeam Echo Sounding Combined With Mass Conservation. Geophys. Res. Lett. 44, 11,051-11,061 (2017).
5. Morlighem, M. MEaSUREs **BedMachine Antarctica**, Version 2. (2020).
6. Estuarine Bathymetric DEMs. National Centers for Environmental Information (NCEI) https://www.ncei.noaa.gov/products/estuarine-bathymetric-digital-elevation-models (2020).
7. TDS Catalog - **NOAA Regional DEMs.** https://www.ngdc.noaa.gov/thredds/catalog/regional/catalog.html.
8. Ryan, W. B. F. et al. Global Multi-Resolution Topography (**GMRT**) synthesis. Geochem. Geophys. Geosystems 10, (2009).
9. AWS S3 Explorer - **NOAA BlueTopo**. https://noaa-ocs-nationalbathymetry-pds.s3.amazonaws.com/index.html#BlueTopo/.
10. Kramer, K. & Shedd, W. W. A 1.4-Billion Pixel Map of the Seafloor: **BOEM**'s Mission to Visualize Dynamic Geology and Identify Natural Seep Sites in the Gulf of Mexico. 2017, OS31C-1411 (2017).
11. Shallow Bathymetry Everywhere. https://shallowbathymetryeverywhere.com/.
12. Mayer, L. et al. The Nippon Foundation—**GEBCO** Seabed 2030 Project: The Quest to See the World's Oceans Completely Mapped by 2030. Geosciences 8, 63 (2018).
13. NCEI. Continuously Updated Digital Elevation Model (**CUDEM**) - 1/9 and 1/3 Arc-Second Resolution Bathymetric-Topographic Tiles. https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ngdc.mgg.dem:999919.
14. Markus, T. et al. The Ice, Cloud, and land Elevation Satellite-2 (**ICESat-2**): Science requirements, concept, and implementation. Remote Sens. Environ. 190, 260–273 (2017).

NOAA National Centers for Environmental Information
www.ncei.noaa.gov

Cooperative Institute for Research in Environmental Sciences
UNIVERSITY OF COLORADO **BOULDER**
cires.colorado.edu