MEaSUREs Greenland Ice Mapping Project (GrIMP) Digital Elevation Model from GeoEye and WorldView Imagery, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Howat, I., A. Negrete, and B. Smith. 2022. *MEaSUREs Greenland Ice Mapping Project (GrIMP) Digital Elevation Model from GeoEye and WorldView Imagery, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/BHS4S5GAMFVY. [Date Accessed].

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

This digital elevation model (DEM) was generated from imagery acquired by the GeoEye-1, and Worldview-1, -2, and -3 Earth imaging satellites operated by Maxar Technologies. In addition to in-track image pairs (i.e., both images collected minutes apart along the same orbital pass), cross-track images were used from different orbits obtained within the in-track imaging geometry and maximum time separation criteria. The DEM is registered to ATLAS/ICESat-2 L3A Land Ice Height, Version 5 (ATL06, V5) data collected in the summers of 2019 and 2020.

ⓘ Version 2 only includes a single DEM created from all available data. Unlike Version 1, "fit," "reg," and quarterly DEMs are not provided.

1.1 Parameters

The final DEM was produced by mosaicking individual DEMs generated by the Surface Extraction from TIN-based Search-space Minimization (SETSM) software. The following parameters are reported for each 30 m × 30 m pixel:

- Height (meters) above the WGS 84 ellipsoid
- Number of individual DEMs used
- Date of oldest DEM used
- Date of most recent DEM used
- Median absolute deviation (MAD) of DEM heights

1.2 File Information

1.2.1 Format

Data are provided as GeoTIFF files.

1.2.2 File Contents

The area covered by the DEM is partitioned into a 6 × 6 grid of 36 tiles, each with 15000 rows x 8310 columns. Tile numbers are zero-indexed and numbered from (0,0) in the bottom-left corner to (5,5) in the upper-right (see Figure 1). Six of the tiles — (0,0), (0,3), (4,0), (5,0), (5,1), and (5,5) — contain no data and are not provided.

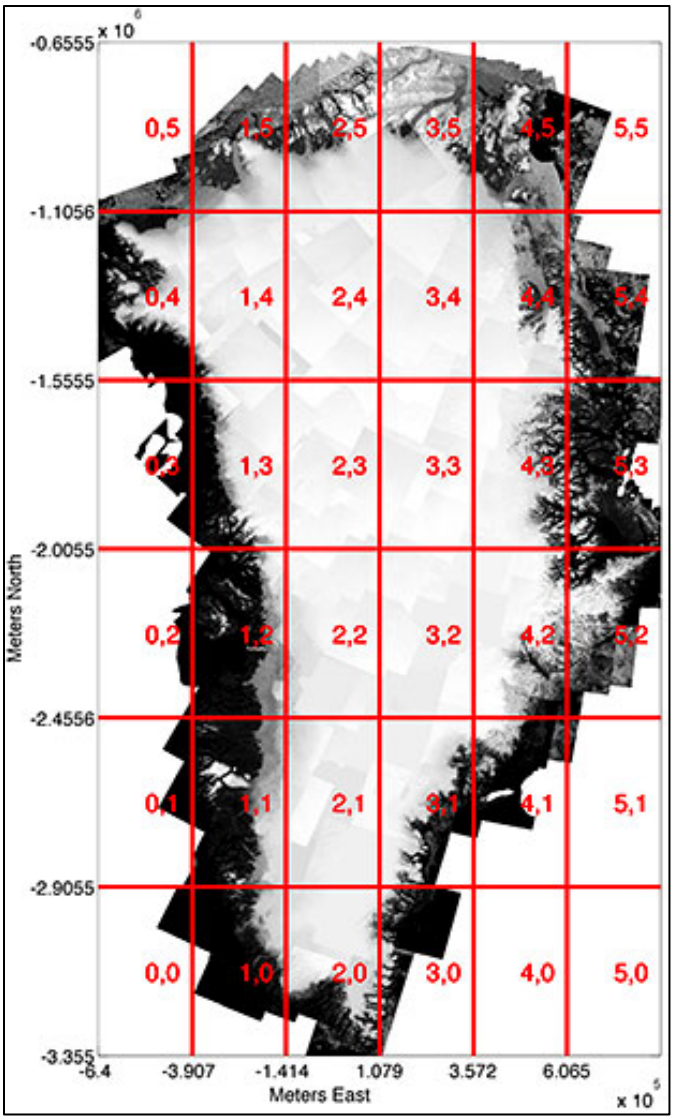

Figure 1. Tile Locations in the DEM Grid

Six GeoTIFFs are available for each tile: one for each of the five parameters listed in “Section 1.1 Parameters,” plus a browse image. The following table describes the contents of each GeoTIFF file:

Table 1. Descriptions of File Contents

Parameter	Description	Data Type
DEM	Height (meters) above the WGS 84 ellipsoid at each pixel	float 32

Parameter	Description	Data Type
DEM count	Number of individual DEMs used to estimate the height at each pixel	uint 8
Minimum Date	Date (days since Jan 1, 2000) of the most recent DEM at each pixel	int 16
Maximum Date	Date (days since Jan 1, 2000) of the oldest DEM at each pixel	int 16
MAD	Median absolute deviation (MAD)[1] of DEM heights at each pixel	float 32
Browse	DEM hillshade image	uint 8

[1]MAD is defined as: $\mathrm{median}(|h_i - \mathrm{median}(h_i)|)$, where h is the set of individual DEM heights from i = 1:n used to estimate the final DEM height.

1.2.3 Naming Convention

Data files utilize the following naming convention:

tile_[x_y]_30m_[param]_v[nn].tif

Example:

tile_0_1_30m_dem_v02.tif
tile_0_1_30m_count_v02.tif
tile_0_1_30m_mindate_v02.tif
tile_0_1_30m_maxdate_v02.tif
tile_0_1_30m_mad_v02.tif
tile_0_1_30m_browse_v02.tif

The following table describes the variables in the file naming convention:

Table 2. File Name Variable Descriptions

Variable	Description
x_y	Location in the tile grid. Tile numbers are numbered from (0,0) in the bottom-left corner to (5,5) in the upper-right.
param	One of: “dem,” “count,” “mindate,” “maxdate,” “mad,” or “browse.” See Table 1 for descriptions.
nn	Two-digit data set version number. E.g., v02 is Version 2.

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 83° N
Southernmost Latitude: 60° N
Easternmost Longitude: 14° W
Westernmost Longitude: 75° W

1.3.2 Resolution

Data are posted at 30 m.

1.3.3 Geolocation

The DEM is provided in a polar stereographic projection. Heights are reported in meters above the WG 84 ellipsoid.

The following tables provide information for geolocating this data set:

Table 3. Geolocation Details

Geographic coordinate system	Unspecified datum based upon the Hughes 1980 ellipsoid
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45

Latitude of true origin	70
Scale factor at longitude of true origin	1
Datum	Not_specified_based_on_Hughes_1980_ellipsoid
Ellipsoid/spheroid	Hughes 1980
Units	meter
False easting	0
False northing	0
EPSG code	3413
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs
Reference	https://epsg.io/3413

Table 4. Grid Details

Grid cell size (x, y pixel dimensions)	30 m × 30 m
Number of rows	15000
Number of columns	8310
Geolocated lower left point in grid	59.1994° N, 55.7983° W
Nominal gridded resolution	30 m
Grid rotation	0
ulxmap – x-axis map coordinate of the center of the upper-left pixel (XLLCORNER for ASCII data)	15 m
ulymap – y-axis map coordinate of the center of the upper-left pixel (YLLCORNER for ASCII data)	2,699,985 m

1.4 Temporal Information

1.4.1 Coverage

15 May 2008 to 19 November 2020

1.4.2 Resolution

N/A

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Version 1 of this data set was generated solely from in-track stereoscopic imagery, and the final DEM was registered to Operation IceBridge data. Version 2 utilizes both in-track and applicable cross-track imagery, a new mosaicking algorithm (described below), and has been registered to ICESat-2 data.

2.2 Acquisition

The DEM was generated from sub-meter resolution, panchromatic imagery acquired by the following Maxar Technologies Earth imaging satellites:

- GeoEye-1
- Worldview-1, -2, and -3

The images are distributed by the National Geospatial Intelligence Agency (NGA) and archived at the Polar Geospatial Center at the University of Minnesota.

The ATLAS/ICESat-2 L3A Land Ice Height, Version 5 (ATL06, V5) data product is archived at NSIDC.

ⓘ In 2020 the NGA clarified that, while source imagery and non-polar DEMs are subject to user restrictions, DEMs over polar regions may be openly distributed.

2.3 Processing

2.3.1 Preprocessing

Images were collected in 13 km to 17 km widths (i.e., swath widths) up to 300 km long and the strips segmented into scenes with approximately 20% overlap. Individual overlapping scenes were paired for stereo processing using the Surface Extraction from TIN-based Search-space Minimization software (SETSM) for producing DEMs (Noh and Howat, 2017). Raster DEMs with a resolution of 2 m were extracted from each scene pair and neighboring scene pairs then mosaicked into strips using the iterative slope regression method of Nuth and Kaab (2011). Unlike Version 1, the individual strips were not filtered.

2.3.2 Algorithm

Due to the large increase in available DEM data since Version 1, a new mosaicking algorithm was applied that utilizes the large number of repeat observations to improve quality. The mosaic is created by first dividing the output domain into 1.2 km × 1.2 km tiles with 100 m of overlap. Then all strips which overlap each tile were subsetted and co-registered to each other and strips with consistently high co-registration errors were removed. A weighted least-squares adjustment was then applied to the coregistration offsets to determine optimal shifts in the x, y, and z directions for each strip.

Adjustment weights were determined from the coregistration errors and the standard DEM errors. Strip DEMs were then shifted and the median values at each grid point, the median absolute deviation (MAD), and the minimum and maximum DEM acquisition times were obtained. A second adjustment was then performed using the vertical offset between each tile and its neighbors in the area of overlap. Finally, the adjusted tiles were merged using a linear edge-distance weighting.

2.3.3 Post-Processing

Once the algorithm described above was completed, the resulting DEM mosaic was inspected for artifacts. While the coregistration-error-based filtering removed most errors, some artifacts due to clouds and shadows, in areas of fewer repeats, were manually masked, and then the mosaic was rebuilt.

To remove artifacts in areas of rapid surface elevation change (e.g., due to thinning and front position changes at outlet glaciers), a single highest-quality DEM was selected to cover the region of rapid change. This DEM was then merged into the mosaic using edge-weighted feathering. These areas can be identified as those which are covered by only one DEM.

2.3.4 Registering

The mosaic was registered in 100 km × 100 km sections to ICESat-2 ATL06 elevations collected in the summer of 2019 and 2020, using the co-registration procedure in Levinson et al. (2013). The tiles were first shifted vertically and horizontally to minimize differences with ICESat-2. Then, a quadratic surface was fitted to the residuals between the shifted DEM tiles and ICESat-2 elevations and subtracted from the DEM. Each 100 km by 100 km tile was then merged with the surrounding tiles using edge-distance weighting. Finally, the GrIMP ocean mask was applied to the DEM with the sea surface height (EGM96) substituted.

2.4 Quality, Errors, and Limitations

Data quality and errors were assessed by first comparing DEM elevations to ICESat-2 ATL06 elevations obtained in the summers of 2019 and 2020. The mean and median differences between the DEM and ATL06 are 10 cm and 0 cm, respectively; this was expected due to the DEMs having been registered to ATL06 during production.

The 68th and 90th percentile linear errors (LE68 and LE90) are 0.28 m and 1.06 m, respectively (i.e., 68% and 90% of the absolute differences between the DEM and ATL06 elevations are within these values). The standard deviation is much larger — 3.87 m — due to the presence of a small number of values (<1%) with large differences (>100 m) arising from spurious ATL06 heights.

3 INSTRUMENTATION

Factsheets (PDF) for the GeoEye-1 and Worldview-1, -2, and -3 satellites can be downloaded from the Maxar | Constellation web page.

4 SOFTWARE AND TOOLS

GeoTIFF files can be accessed using GIS software such as QGIS and ArcGIS.

5 VERSION HISTORY

Table 5. Version History Summary

Version	Release Date	Description of Changes
Version 2.0	July 2022	• DEM generated from both in-track image pairs and cross-track images. • DEM registered to ATLAS/ICESat-2 L3A Land Ice Height, Version 5 (ATL06, V5) • Algorithm revised to utilize large increase in available DEM data since Version 1. • Version 2 only includes a single DEM created from all available data. "fit," "reg," and quarterly DEMs are not provided.
Version 1.1	June 2020	Version number added to file names.
Version 1.0	March 2017	Initial release

6 RELATED DATA SETS

- MEaSUREs Greenland Ice Mapping Project (GIMP) Digital Elevation Model, Version 1
- ATLAS/ICESat-2 L3A Land Ice Height, Version 5

7 RELATED WEBSITES

- MEaSUREs Data at NSIDC
- GrIMP Data at NSIDC
- Maxar | Constellation

8 CONTACTS AND ACKNOWLEDGMENTS

This work was performed as part of the EarthDEM project supported by the National Geospatial Intelligence Agency (NGA) and National Science Foundation (NSF). The SETSM software was run on Blue Waters, a high performance computing system at the National Center for Supercomputing Applications.

8.1 Investigators

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9 REFERENCES

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10 DOCUMENT INFORMATION

10.1 Publication Date

June 2022

10.2 Date Last Updated

June 2022