



IceBridge DMS L3 Ames Stereo Pipeline Photogrammetric DEM, Version 1

USER GUIDE

How to Cite These Data

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

Alexandrov, O., S. McMichael, and R. A. Beyer. 2018. *IceBridge DMS L3 Ames Stereo Pipeline Photogrammetric DEM, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.
<https://doi.org/10.5067/HYV1T0G7LVHE>. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/IODEM3>



National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set represents a collection of digital elevation models (DEMs) that were created using the [NASA Ames Stereo Pipeline](#). The final DEMs were obtained by processing stereo images from the *IceBridge DMS L0 Raw Imagery* data set, along with NASA's Land, Vegetation, and Ice Sensor (LVIS) and Airborne Topographic Mapper (ATM) lidar data from the *IceBridge LVIS L2 Geolocated Surface Elevation Product* and *IceBridge ATM L1B Elevation and Return Strength* data sets, respectively. The closely related data set *IceBridge DMS L3 Ames Stereo Pipeline Orthorectified Images* provides the corresponding orthorectified images in GeoTIFF format.

1.1 Parameters

The DEMs in this data set depict ice sheet and glacier elevation in meters for regions of the Arctic, Greenland, and Antarctica.

1.2 Sample Data Record

Figure 1 displays contents from the file `IODEM3_20161026_180539_00005_DEM.tif`, collected over Antarctica on 26 October 2016.

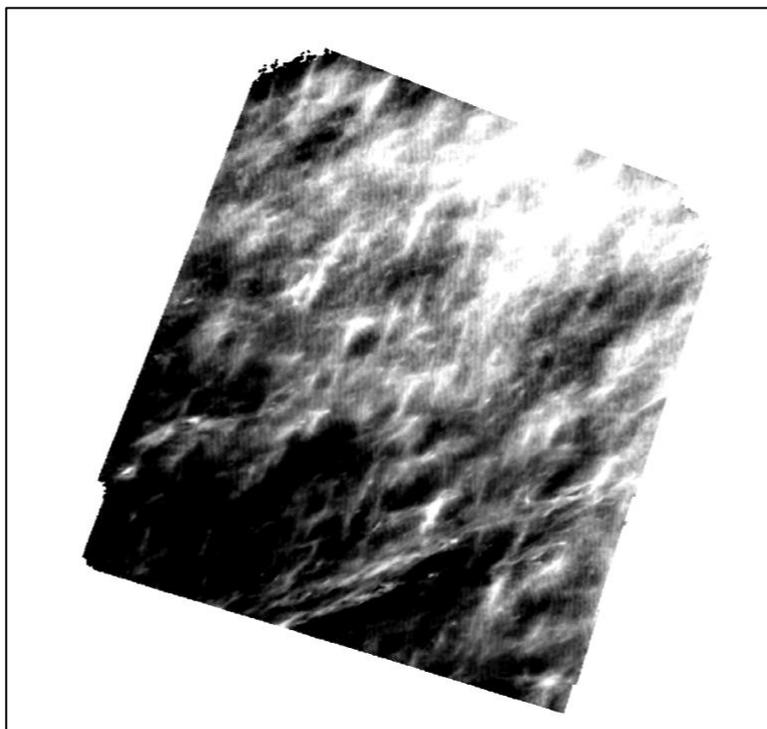


Figure 1. Imagery from file `IODEM3_20161026_180539_00005_DEM.tif`

The listing below shows the metadata embedded in the same file as in Figure 1, extracted using the `gdalinfo` command line utility available from the [Geospatial Data Abstraction Library \(GDAL\)](https://gdal.org/) website.

```

gdalinfo IODEM3_20161026_180539_00005_DEM.tif

Driver: GTiff/GeoTIFF
Files: IODEM3_20161026_180539_00005_DEM.tif
       IODEM3_20161026_180539_00005_DEM.tif.aux.xml
Size is 1224, 1285
Coordinate System is:
PROJCS["unnamed",
  GEOGCS["WGS 84",
    DATUM["WGS_1984",
      SPHEROID["WGS 84",6378137,298.257223563,
        AUTHORITY["EPSG","7030"]],
      AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0],
    UNIT["degree",0.0174532925199433],
    AUTHORITY["EPSG","4326"]],
  PROJECTION["Polar_Stereographic"],
  PARAMETER["latitude_of_origin",-71],
  PARAMETER["central_meridian",0],
  PARAMETER["scale_factor",1],
  PARAMETER["false_easting",0],
  PARAMETER["false_northing",0],
  UNIT["metre",1,
    AUTHORITY["EPSG","9001"]]]]
Origin = (-206718.657754999992903,74861.700677000000724)
Pixel Size = (0.373322000000000,-0.373322000000000)
Metadata:
  AREA_OR_POINT=Area
Image Structure Metadata:
  COMPRESSION=LZW
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  ( -206718.658,  74861.701) ( 70d 5'33.01"W, 87d58'36.18"S)
Lower Left  ( -206718.658,  74381.982) ( 70d12'36.50"W, 87d58'41.58"S)
Upper Right ( -206261.712,  74861.701) ( 70d 3' 6.76"W, 87d58'50.41"S)
Lower Right ( -206261.712,  74381.982) ( 70d10'10.96"W, 87d58'55.82"S)
Center      ( -206490.185,  74621.841) ( 70d 7'51.80"W, 87d58'46.00"S)
Band 1 Block=256x256 Type=Float32, ColorInterp=Gray
  Min=2561.843 Max=2562.872
  Minimum=2561.843, Maximum=2562.872, Mean=2562.267, StdDev=0.112
  NoData Value=-3.4028234663852886e+38
  Metadata:
    STATISTICS_MAXIMUM=2562.8723144531
    STATISTICS_MEAN=2562.2667888422
    STATISTICS_MINIMUM=2561.8427734375
    STATISTICS_STDDEV=0.11187670120227

```

Figure 2. Metadata information for file IODEM3_20161026_180539_00005_DEM.tif

1.3 File Information

1.3.1 Format

The data files are gridded, 32-bit floating point GeoTIFF (.tif) files, created using lossless LZW compression. Browse files in GeoTIFF format and metadata files in XML format are also provided.

1.3.2 Naming Convention

Files are named according to the following convention and as described in Table 1.

Example file names:

```
IODEM3_20170725_122524_00315_DEM.tif
IODEM3_20170725_122524_00315_DEM_browse.tif
IODEM3_20170725_122524_00315_DEM.tif.xml
```

File naming convention:

```
IODEM3_YYYYMMDD_HHMMSS_NNNNN_DEM.ext
IODEM3_YYYYMMDD_HHMMSS_NNNNN_DEM_browse.ext
```

Table 1. File Naming Convention

Variable	Description
IODEM3	Short name for IceBridge DMS L3 Ames Stereo Pipeline Photogrammetric DEM
YYYYMMDD	Year, month, and day of measurement
HHMMSS	Hours, minutes, and seconds of measurement
NNNNN	Frame number from the digital mapping system (DMS) camera
DEM	File content type: digital elevation model
browse	Indicator for browse files. Note: browse files are provided in GeoTIFF (.tif) format.
.ext	File extension: .tif = GeoTIFF file .tif.xml = XML metadata file

1.4 Spatial Information

1.4.1 Coverage

Spatial coverage for this data set currently includes the Arctic, Greenland, and Antarctica.

Arctic/Greenland:

- Southernmost latitude: 60° N
- Northernmost latitude: 90° N
- Westernmost longitude: 180° W
- Easternmost longitude: 180° E

Antarctica:

- Southernmost latitude: 90°S
- Northernmost latitude: 53°S
- Westernmost longitude: 180° W
- Easternmost longitude: 180° E

1.4.2 Resolution

The resolution of the DEMs depends on the height of the aircraft above the ground, and thus varies from file to file. Since the resolution is not fixed, the number of grid rows and columns in every DEM also varies. Typically, the DEMs have a horizontal resolution of 40 cm per pixel; however, this value can be as large as several meters per pixel, if the aircraft was flown at high altitudes. The vertical accuracy varies from 5 cm to several meters, as compared to the lidar instrument. This value also depends on the altitude at which the aircraft was flown.

Note: The spatial extent of each DEM is smaller than the spatial extent of the corresponding input image. This discrepancy is due to the fact that it takes two images to make a DEM, hence the spatial extent of the DEM is equal to the intersection of the spatial extents of the input images.

1.4.3 Geolocation

The following table provide information for geolocating this data set.

Table 2. Geolocation Details for the Arctic/Greenland and Antarctica Data

	Arctic/Greenland	Antarctica
Geographic coordinate system	WGS 84	WGS 84
Projected coordinate system	WGS 84 / NSIDC Sea Ice Polar Stereographic North	WGS 84 / Antarctic Polar Stereographic
Longitude of true origin	-45° E	0°
Latitude of true origin	70° N	71° S
Scale factor at longitude of true origin	1	1

	Arctic/Greenland	Antarctica
Datum	WGS 84	WGS 84
Ellipsoid/spheroid	WGS 84	WGS 84
Units	meters	meters
False easting	0	0
False northing	0	0
EPSG code	3413	3031
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	+proj=stere +lat_0=-90 +lat_ts=- 71 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	EPSG: 3413	EPSG: 3031

1.5 Temporal Information

1.5.1 Coverage

16 October 2009 to 25 July 2017

1.5.2 Resolution

IceBridge campaigns are conducted on an annually repeating basis. Arctic and Greenland campaigns are typically conducted during March, April, and May. Antarctic campaigns are typically conducted during October and November.

2 DATA ACQUISITION AND PROCESSING

2.1 Background and Acquisition

The NASA Ames Stereo Pipeline was used in all processing steps. The stereo DEM creation starts with raw DMS images from the *IceBridge DMS L0 Raw Imagery* data set, camera intrinsic calibration data from the *IceBridge DMS L0 Camera Calibration* data set, and camera extrinsic (i.e., navigation) data from the *IceBridge POS/AV L1B Corrected Position and Attitude Data* data set. These data sets are often augmented for accuracy by backsolving with camera information from orthorectified images from the *IceBridge DMS L1B Geolocated and Orthorectified Images* data set. This process produces the initial camera information for each image.

2.2 Processing

After acquiring the initial camera information for each image, camera positions and orientations are refined using bundle adjustment. This process collects tie points between each pair of images, and minimizes the reprojection error among the two images in each pair. Bundle adjustments make every image/camera pair self-consistent, but not necessarily aligned correctly to a global reference system; this last step is handled later on.

For each image pair, the More Global Matching (MGM) stereo correlation algorithm is employed to find dense correspondences among the image pixels. Using the camera information, the obtained pixel correspondences are triangulated, which results in a 3D point cloud. This cloud is then further processed into a 3D DEM.

Using the Point-to-Plane variant of the Iterative Closest Point (ICP) algorithm, the DEM is aligned to underlying lidar data that were acquired simultaneously with the DMS images. The alignment is done with ASP's tool `pc_align`, which uses the [libpointmatcher library](#) to transform the data into the world coordinate system. The lidar data that were used to create the DEMs are either in LVIS or ATM format and were acquired from the *IceBridge LVIS L2 Geolocated Surface Elevation Product* and the *IceBridge ATM L1B Elevation and Return Strength* data sets, respectively. After each DEM is aligned, it is blended with neighboring aligned DEMs to prevent end-of-image seams, enhance the signal-to-noise ratio in each DEM, make neighboring DEMs self-consistent, and reduce errors that arise from imperfect camera calibration.

For certain flights, such as the Greenland Spring 2014 campaign, camera calibration was highly inaccurate. In such cases, the camera intrinsic parameters for each flight are optimized using the underlying lidar data and a dense set of correspondences, or bundle adjustments, between two (and, whenever possible, three) consecutive images as constraints. This results in DEMs that are much more closely aligned to the underlying lidar data and more self-consistent among themselves. Furthermore, this process reduces the intrinsic ray intersection error for each DEM; in effect, this reduces the minimal distance between rays that emanate from the left and the right cameras and that are meant to intersect on the surface of the DEM.

Each DEM with a given frame number is obtained by correlating two input images: one with the same frame number and another with the following frame number. On rare occasions, when the images are spatially too close together, the second image used for stereo correlation is not the immediately adjacent frame, but the following frame.

2.3 Quality, Errors, and Limitations

The underlying accuracy of the measurements depends on a number of factors, including:

- **Camera calibration and stability.** This typically manifests in two forms:
 - Focal length errors, which result in scale factor errors in the Z-dimension of the raw frame. The lidar correction algorithm is designed to correct this.
 - Distortion errors. In some cases, distortion estimation routines in the ASP software package result in a poor lens distortion model. This can result in DEMs that are slightly concave or convex on the edges.
- **GPS trajectory accuracy for DMS exposure locations.** This is generally not a concern due to the correction against lidar data.
- **Ability to match points between frames,** for both sparse and dense matching steps. In some cases, especially with low-contrast images that include fog or clouds, the ASP software may not be able to match points. This can result in a failure to produce any depth map, or can occasionally produce depth maps with artificial features. In some cases, low contrast sea ice or sheet ice can exhibit spikes in the final DEM. JPEG compression artifacts can amplify this effect.
- **Accuracy of the ATM/LVIS data sets.** Given the lidar correction process in use, any systematic errors in the ATM Level-1B or the LVIS Level-2 data can impact the photogrammetric DEMs.
- **Accuracy of the alignment process for depth map correction.** The correction process requires the lidar point cloud and the raw image footprint to be properly aligned. Large initial displacements lead to errors in the correction processes. In these cases, the mean vertical error is typically still near zero.
- **Accuracy of the alignment process for DEM blending.** If the DEMs fail to align correctly with the underlying lidar data, they won't be aligned correctly among themselves either, which affects the accuracy of the blending process.

2.4 Instrumentation

2.4.1 Description

DMS provides natural color or panchromatic tracking imagery from low- and medium-altitude research aircraft. The system configuration includes a 21-megapixel Canon EOS 5D Mark II digital camera, computer-controlled intervalometer, and an Applanix POS/AV precision orientation system. In-flight operators maximize image quality with adjustments to exposure and intervalometer settings.

2.4.2 Trajectory and Attitude

The trajectory and attitude data used in processing were acquired by the DMS Applanix POS/AV 510 system and provided by the DMS instrument group.

3 SOFTWARE AND TOOLS

Software that recognizes the GeoTIFF file format is recommended for these images (see [libGeoTIFF](#)). Along with coordinate and projection information, additional metadata are

embedded in the GeoTIFF files. The additional fields can be extracted using the `gdalinfo` command line utility available from the [Geospatial Data Abstraction Library \(GDAL\)](#) website.

4 RELATED DATA SETS

[IceBridge DMS L3 Ames Stereo Pipeline Orthorectified Images](#)
[IceBridge LVIS L2 Geolocated Surface Elevation Product](#)
[IceBridge ATM L1B Elevation and Return Strength](#)
[IceBridge DMS L0 Camera Calibration](#)
[IceBridge DMS L0 Raw Imagery](#)
[IceBridge DMS L1B Geolocated and Orthorectified Images](#)
[IceBridge DMS L3 Photogrammetric DEM](#)
[IceBridge CAMBOT L1B Geolocated Images](#)
[GLAS/ICESat 1km Laser Altimetry Digital Elevation Model of Greenland](#)

5 RELATED WEBSITES

[NASA Ames Stereo Pipeline](#)
[NASA Digital Mapping System web page](#)
[IceBridge data website at NSIDC](#)
[IceBridge website at NASA](#)
[ICESat/GLAS website at NASA Wallops Flight Facility](#)
[ICESat/GLAS website at NSIDC](#)

6 CONTACTS AND ACKNOWLEDGMENTS

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7 DOCUMENT INFORMATION

7.1 Publication Date

13 August 2018

7.2 Date Last Updated

11 February 2020