IceBridge DMS L3 Ames Stereo Pipeline Orthorectified Images, 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 Orthorectified Images, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/R3TN4LOIKDMC. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IODIM3

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set represents a collection of orthorectified images that were created using the NASA Ames Stereo Pipeline. The final images 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 Photogrammetric DEM* provides the corresponding digital elevation models (DEMs) in GeoTIFF format.

1.1 Parameters

The orthorectified images in this data set depict ice sheets and glaciers for regions of the Arctic, Greenland, and Antarctica.

1.2 Sample Data Record

Figure 1 displays contents from the file `IODIM3_20170725_175750_06972_ORTHO.tif`, collected on 25 July 2017.

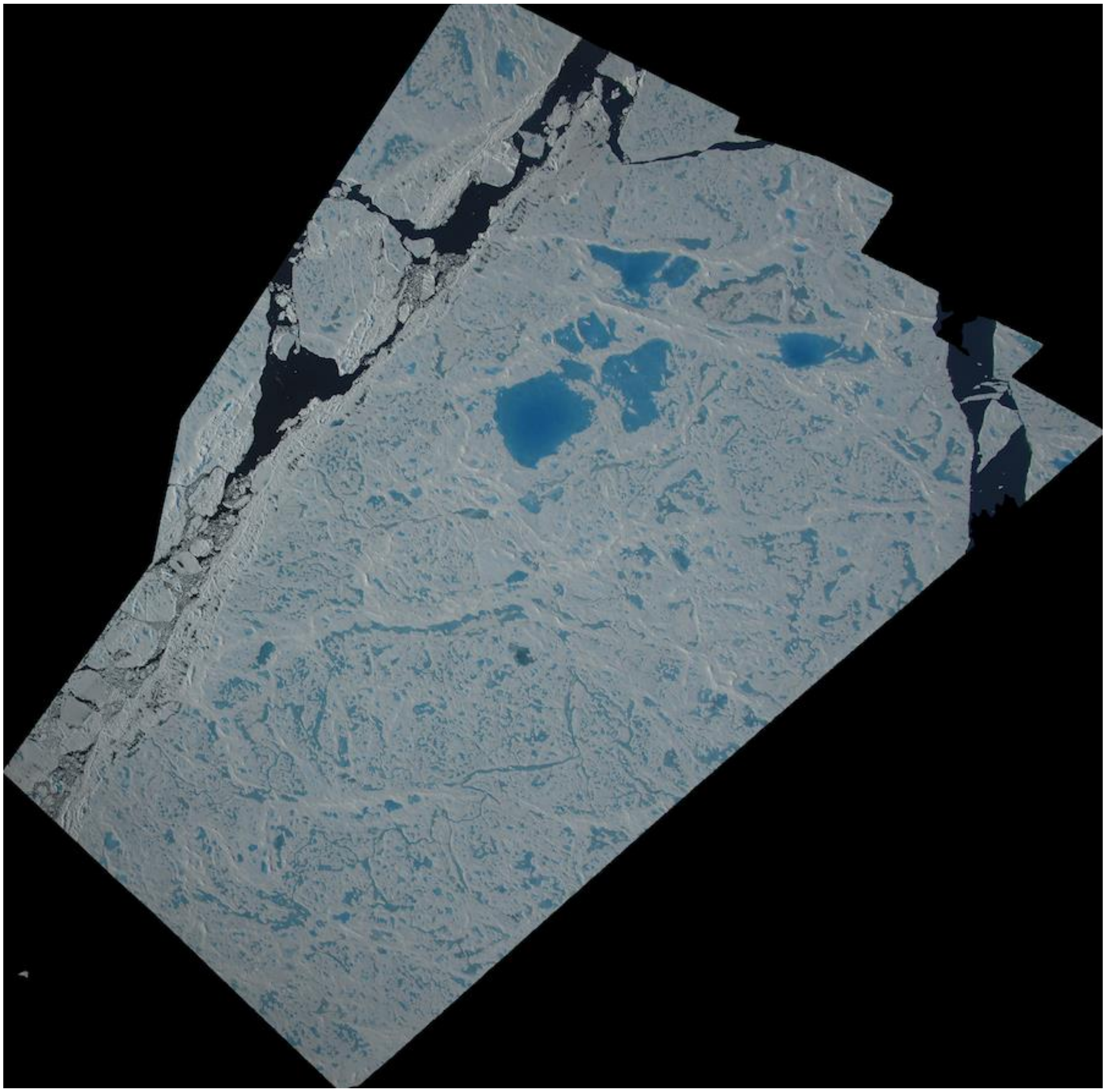

Figure 1. Imagery from file `IODIM3_20170725_175750_06972_ORTHO.tif`

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) website.

```
gdalinfo IODIM3_20170725_175750_06972_ORTHO.tif
Driver: GTiff/GeoTIFF
Files: IODIM3_20170725_175750_06972_ORTHO.tif
Size is 6453, 6387
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",70],
   PARAMETER["central_meridian",-45],
   PARAMETER["scale_factor",1],
   PARAMETER["false_easting",0],
   PARAMETER["false_northing",0],
   UNIT["metre",1,
      AUTHORITY["EPSG","9001"]]]
Origin = (-363027.274469718337059,-554805.695960387587547)
Pixel Size = (0.394514888525009,-0.394514888525009)
Metadata:
  AREA_OR_POINT=Area
Image Structure Metadata:
  COMPRESSION=JPEG
  INTERLEAVE=PIXEL
Corner Coordinates:
Upper Left  ( -363027.274, -554805.696) ( 78d11'52.87"W, 83d53' 6.12"N)
Lower Left  ( -363027.274, -557325.463) ( 78d 4'45.02"W, 83d51'56.19"N)
Upper Right ( -360481.470, -554805.696) ( 78d 0'48.75"W, 83d53'52.20"N)
Lower Right ( -360481.470, -557325.463) ( 77d53'42.12"W, 83d52'42.13"N)
Center      ( -361754.372, -556065.579) ( 78d 2'47.19"W, 83d52'54.20"N)
Band 1 Block=6453x16 Type=Byte, ColorInterp=Red
Band 2 Block=6453x16 Type=Byte, ColorInterp=Green
Band 3 Block=6453x16 Type=Byte, ColorInterp=Blue
```

Figure 2. Metadata information for file `IODIM3_20170725_175750_06972_ORTHO.tif`

1.3 File Information

1.3.1 Format

The data files are gridded, 8-bit floating point GeoTIFF (`.tif`) files, created using JPG compression. Browse files in JPG 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:

```
IODIM3_20170725_175750_06972_ORTHO.tif
IODIM3_20170725_175750_06972_ORTHO.jpg
IODIM3_20170725_175750_06972_ORTHO.tif.xml
```

File naming convention:

```
IODIM3_YYYYMMDD_HHMMSS_NNNNN_ORTHO.ext
```

Table 1. File Naming Convention

Variable	Description
`IODIM3`	Short name for IceBridge DMS L3 Ames Stereo Pipeline Orthorectified Images
`YYYYMMDD`	Year, month, and day of measurement
`HHMMSS`	Hours, minutes, and seconds of measurement
`NNNNN`	Frame number from the digital mapping system (DMS) camera
`ORTHO`	File content type: orthorectified images
`.ext`	File extension: `.tif` = GeoTIFF data file `.jpg` = JPG browse image `.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 images 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 file also varies. On average, the images have a resolution of 10 to 20 cm per pixel.

1.4.3 Geolocation

WGS 84 / NSIDC Sea Ice Polar Stereographic North (EPSG: 3413)
WGS 84 / Antarctic Polar Stereographic (EPSG: 3031)

1.5 Temporal Information

1.5.1 Coverage

16 October 2009 to 25 July 2017

1.5.2 Resolution

IceBridge campaigns were conducted on an annually repeating basis. Arctic and Greenland campaigns were typically conducted during March, April, and May. Antarctic campaigns were 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 Produc t*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.

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.

The orthorectified images are created by projecting onto the corresponding DEM; several neighboring DEMs are merged to create a new DEM that is large enough so that the full spatial extent of the image can be projected onto it. Thus, the size of the orthorectified image is equal to the size of the original input image.

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 ACKNOWLEDGMENTS

This project was funded by Tom Wagner at NASA Headquarters to process all Operation IceBridge DMS camera images and create Digital Elevation Models using the NASA Ames Stereo Pipeline.

4 DOCUMENT INFORMATION

4.1 Publication Date

August 2018

4.2 Date Last Updated

August 2025