



# IceBridge DMS L1B Geolocated and Orthorectified Images, Version 1

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## USER GUIDE

### How to Cite These Data

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

Dominguez, R. 2010, updated 2018. *IceBridge DMS L1B Geolocated and 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/OZ6VNOPMPRJ0>. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT [NSIDC@NSIDC.ORG](mailto:NSIDC@NSIDC.ORG)

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/IODMS1B>



National Snow and Ice Data Center

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# 1 DETAILED DATA DESCRIPTION

The DMS airborne digital camera acquires high resolution natural color and panchromatic imagery from low and medium altitude research aircraft. Measurements are embedded in the image files, including coordinate and projection information, GPS Date, GPS Time, Pitch, Roll, Altitude, FStop, Shutter Speed, and Mode. The related data set, *IceBridge DMS L0 Camera Calibration*, contains corresponding DMS camera calibration summary reports in PDF format for IceBridge DMS missions flown over Antarctica and Greenland. To access these calibration reports by campaign, see the user guide for the *IceBridge DMS L0 Camera Calibration* data set.

## 1.1 Format

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The DMS Level-1B Geolocated and Orthorectified Images are GeoTIFF (.tif) files. For each GeoTIFF there is an associated browse file in JPEG format (.jpg) and an XML file (.xml) containing additional metadata.

## 1.2 File Naming Convention

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The GeoTIFF files are named according to the following convention and as described in Table 1.

### Example File Names

```
DMS_1781728_00030_20161118_15443827.tif
DMS_1000109_00551_20091016_15114115.tif.xml
DMS_1000109_00551_20091016_15114115.tif_brws.jpg
```

### Naming Convention

```
DMS_ffffff_FFFFFF_YYYYMMDD_HHmmsshh.xxx
```

Table 1. File Naming Convention

Variable	Description
DMS	Digital Mapping System camera
ffffff	Flight number
FFFFFF	Frame Number (all GeoTIFF files have 5 digit frame numbers)
YYYY	Four-digit year image acquired

MM	Two-digit month image acquired
DD	Two-digit day image acquired
HH	Two-digit hour image acquired
mm	Two-digit minute image acquired
ss	Two-digit second image acquired
hh	Two-digit hundredths of a second image acquired
.xxx	File extension: .tif (GeoTIFF files) .tif.xml (XML metadata files) .tif_brws.jpg (browse files in JPEG format)

**NOTE:** File names for the 2009 Antarctica campaign include a `_v02` indication, for example:

```
DMS_1000109_00551_20091016_15114115_v02.tif
DMS_1000109_00551_20091016_15114115_v02.tif.xml
DMS_1000109_00551_20091016_15114115_v02.tif_brws.jpg
```

See the Version History and Special Processing Notes sections for more information about the 2009 Antarctica data.

**NOTE:** During ingest of new IODMS1B data, `RecentInserts` files are temporarily stored with the data files. These files contain listings of the data files that have been added to the data set. After ingest is complete, the recent insert files are removed. Example file name: `DPRecentInserts_IODMS1B_001_20130820`.

### 1.3 File Size

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GeoTIFF files range from approximately 2 MB to 248 MB. The total GeoTIFF file size is approximately 79 TB.

## 1.4 Spatial Coverage

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Spatial coverage includes Greenland, Antarctica, and Arctic and Antarctic sea ice areas, represented by the two coverages noted below.

### Arctic and Greenland:

Southernmost Latitude: 60° N

Northernmost Latitude: 90° N

Westernmost Longitude: 180° W

Easternmost Longitude: 180° E

### Antarctic:

Southernmost Latitude: 90° S

Northernmost Latitude: 53° S

Westernmost Longitude: 180° W

Easternmost Longitude: 180° E

### 1.4.1 Spatial Resolution

The DMS Level-1B spatial resolution ranges from 0.015 m to 2.5 m. Pixel size is dependent on flight altitude and referenced DEM. Spatial resolution is 10 cm for images acquired at 1500 ft AGL.

### 1.4.2 Projection and Grid Description

Arctic: Polar Stereographic Standard Parallel 70° N, Longitude of the origin (central meridian): 45° W, WGS 84 ellipsoid.

Antarctica: Polar Stereographic Standard Parallel 71° S, Longitude of the origin (central meridian): 0°, WGS 84 ellipsoid.

**Note:** For the 2010 Antarctica campaign only, the standard parallel for sea ice images is 70° S.

## 1.5 Temporal Information

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16 October 2009 to 19 April 2018

## 1.5.1 Temporal Resolution

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

## 1.6 Parameter or Variable

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### 1.6.1 Parameter Description

The DMS Level-1B Geolocated and Orthorectified Images are natural color and panchromatic imagery. The GeoTIFF files include the following embedded information: GPS Date, GPS Time, Pitch, Roll, Altitude, FStop, Shutter Speed, Mode, and Coordinate and Projection information.

### 1.6.2 Sample Data Record

The image below is a selected area of the image  
file: DMS\_1000109\_01938\_20091016\_17423840.tif

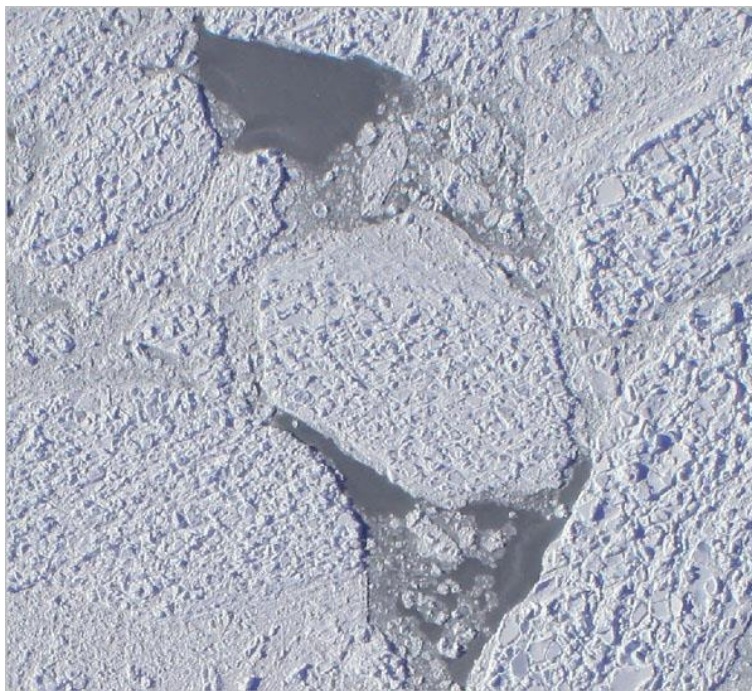


Figure 1. Sample Data Record

The listing below shows the information embedded in the GeoTIFF image file `DMS_1000109_01938_20091016_17423840.tif` displayed above.

```

Driver: GTiff/GeoTIFF
Files: DMS_1000109_01938_20091016_17423840.tif
      DMS_1000109_01938_20091016_17423840.tif.aux.xml
Size is 9317, 9325
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 = (-1306208.478706666700000,-1118593.710328006700000)
Pixel Size = (0.145206750506054,-0.145206750506054)
Metadata:
  GPSTime=2009-10-16
  GPSTime=17:42:38.40
  Pitch=1.58 deg
  Roll=-6.84 deg
  Altitude=515 m
  FStop=8
  ShutterSpeed=11
  Mode=Color
  AREA_OR_POINT=Area
Image Structure Metadata:
  COMPRESSION=JPEG
  INTERLEAVE=PIXEL
Corner Coordinates:
Upper Left  (-1306208.479,-1118593.710) (130d34'32.36"W, 74d16'4.41"S)
Lower Left  (-1306208.479,-1119947.763) (130d36'35.65"W, 74d15'35.74"S)
Upper Right (-1304855.587,-1118593.710) (130d36'17.97"W, 74d16'37.84"S)
Lower Right (-1304855.587,-1119947.763) (130d38'21.28"W, 74d16'9.15"S)
Center      (-1305532.033,-1119270.737) (130d36'26.82"W, 74d16'6.79"S)
Band 1 Block=9317x16 Type=Byte, ColorInterp=Red
  Min=0.000 Max=255.000
  Minimum=0.000, Maximum=255.000, Mean=41.123, StdDev=74.856
  Metadata:
    STATISTICS_MINIMUM=0
    STATISTICS_MAXIMUM=255
    STATISTICS_MEAN=41.123136611245
    STATISTICS_STDDEV=74.856296000767
Band 2 Block=9317x16 Type=Byte, ColorInterp=Green
  Min=0.000 Max=255.000
  Minimum=0.000, Maximum=255.000, Mean=43.262, StdDev=78.261
  Metadata:
    STATISTICS_MINIMUM=0
    STATISTICS_MAXIMUM=255
    STATISTICS_MEAN=43.262296099753
    STATISTICS_STDDEV=78.260868118243
Band 3 Block=9317x16 Type=Byte, ColorInterp=Blue
  Min=0.000 Max=255.000
  Minimum=0.000, Maximum=255.000, Mean=46.395, StdDev=83.255
  Metadata:
    STATISTICS_MINIMUM=0
    STATISTICS_MAXIMUM=255
    STATISTICS_MEAN=46.395121236196
    STATISTICS_STDDEV=83.255412338191

```



## 2 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 is embedded in the GeoTIFF files. NSIDC provides a [MATLAB GeoTIFF reader](#) that reads time and position from the GeoTIFF data files. The additional fields can be extracted using tools such as [gdalinfo](#) from the Geospatial Data Abstraction Library (GDAL). Visit the [GDAL website](#) for more information.

## 3 DATA ACQUISITION AND PROCESSING

### 3.1 Theory of Measurements

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This DMS data processing package is based on a rigorous camera model used to generate perspective scenes and map between the image plane and the ground. In order to transform from a 2D image frame to 3D world coordinates, the following parameters must be known: camera focal length, pixel size, principal point, lens distortion coefficients, and camera position and attitude (Roll, Pitch, and Heading). These parameters are used in a photogrammetric rotation between the image-plane and the target coordinates process to orthorectify images into real-world coordinates on a pixel-by-pixel basis.

Two instruments are used in the airborne data acquisition: an Applanix POS/AV navigation system and a Canon EOS II digital camera. The POS/AV is a combined inertial measurement unit (IMU) and Global Positioning System (GPS) and provides precise position and attitude information.

The basic photogrammetry relation between a point  $(x, y)$  on the image frame and the ground surface point  $(Xg, Yg, Zg)$  can be expressed using Equation 1:

$$P_f = k \cdot \underline{R_{cam}} \cdot \underline{P_g} \quad (\text{Equation 1})$$

Table 2. Basic Photogrammetry Relation Parameters

Variable	Description
$k$	Scale factor
$R_{cam}$	Camera rotation matrix to transform between 2D image frame and 3D grid north coordinates
$P_f$	Image frame point vector of $(x-x_p, y-y_p, -f)$ , where $(x_p, y_p)$ is the principal point, and $f$ is the focal length
$P_g$	Ground surface point vector of $(X_g-X_0, Y_g-X_0, Z_g-Z_0)$ , where $(X_0, Y_0, Z_0)$ is the perspective center vector

The  $R_{cam}$  rotation matrix in Equation 1 uses a grid north coordinate system with three rotation angles, Omega, Phi, and Kappa. However, the navigation system collects Roll, Pitch, and Heading angles with a true north coordinate. The collected angles are different from the Omega, Phi, and Kappa angles.

Assuming the navigation system and camera offset can be measured and adjusted, a rotation correction ( $R_b$ ) between the IMU and the camera angular misalignment can be estimated using a boresight angle correction procedure. The  $R_{cam}$  rotation matrix adds the  $R_b$  correction matrix as described in Equation 2:

$$\underline{R_{cam}} = \underline{R_b} \cdot \underline{R_{nav}} \quad \text{(Equation 2)}$$

Table 3. Camera Rotation Matrix Parameters

Variable	Description
$R_b$	Rotation correction between the IMU and the camera angular misalignment
$R_{nav}$	Rotation matrix with Omega, Phi, and Kappa without rotation correction between navigation system and DMS camera

The orientation of the DMS camera is 90 degrees counter-clockwise from the flight/navigation direction.  $R_{nav}$  from Equation 2 is therefore rewritten as described in Equation 3:

$$R_{nav} = R_c \cdot Trans(R_{gnav}) \cdot R_g \tag{Equation 3}$$

Table 4. Rotation Matrix Parameters

Variable	Description
Rc	Rotation matrix for the 90 degree counter-clockwise difference between the flight direction and the camera mounting direction
Rg	Rotation matrix to correct between grid north and true north
Trans(Rgnav)	Matrix transpose of Rgnav, a rotation matrix with Roll, Pitch, Yaw (where Yaw = -Heading).

## 3.2 Data Acquisition Methods

DMS acquires standard JPEG imagery, which are stored via Ethernet on a supporting laptop computer. This computer also runs the EOS camera utility software to monitor and control image exposure. Frame capture is controlled using an external intervalometer. The intervalometer provides a Transistor-Transistor-Logic (TTL) pulse to the navigation system which enables precise timing for each image capture.

## 3.3 Derivation Techniques and Algorithms

### 3.3.1 DMS Camera Calibration

Lens calibration is fundamental to rigorous camera modeling. It is used to eliminate geometric distortion. Calibrated camera interior correction parameters include:

- Focal length
- Principal point (xp, yp)
- 3rd-order (k1), 5th-order (k2), and 7th-order (k3) terms of radial distortion correction
- Coefficients of decentering distortion (p1, p2)

The corrected image frame coordinates (xc, yc) can be calculated from the measured coordinates (xm, ym) by using the Equations 4 and 5:

$$x = xm - xp \tag{Equation 4}$$

$$y = y_m - y_p \tag{Equation 5}$$

Table 5. Corrected Image Frame Coordinates

Variable	Description
$x_m$	Measured coordinate x
$x_p$	Principle point x
$y_m$	Measured coordinate y
$y_p$	Principle point y

x and y now refer to the principal point:

$$r^2 = x^2 + y^2 \tag{Equation 6}$$

$$\underline{dr} = k_1 \cdot r^3 + k_2 \cdot r^5 + k_3 \cdot r^7 \tag{Equation 7}$$

$$\underline{xc} = \underline{xm} - \underline{xp} + \underline{x \cdot dr / r} + p_1 \cdot (r^2 + 2x^2) + 2 \cdot p_2 \cdot x \cdot y \tag{Equation 8}$$

$$\underline{yc} = \underline{ym} - \underline{yp} + \underline{y \cdot dr / r} + p_2 \cdot (r^2 + 2y^2) + 2 \cdot p_1 \cdot x \cdot y \tag{Equation 9}$$

Table 6. x and y to Principle Point

Variable	Description
r	Distance from the principal point of the lens
dr	Radial distortion from the principal point
k1	3rd-order term of radial distortion correction
k2	5th-order term of radial distortion correction
k3	7th-order term of radial distortion correction

xc	Corrected image frame coordinate x
yc	Corrected image frame coordinate y
p1, p2	Coefficients of decentering distortion

### 3.3.2 Offset Adjustment between Navigation System and Camera

The three dimensional distances between camera principle point, IMU, and GPS antenna are integrated into the final navigation data solution. This enables the rotation matrix  $Rb$  to properly represent the boresight correction angles.

The measured vector (dx, dy, dz) is fully integrated into the post flight navigation data process. Therefore, the camera position is adjusted to the same navigation system origin.

### 3.3.3 Boresight Correction

If we combine Equations 2 and 3,  $Rcam$  can be rewritten as:

$$\underline{Rcam} = \underline{Rb} \cdot \underline{Rc} \cdot \underline{Trans(Rgnav)} \cdot \underline{Rg}$$

(Equation 10)

Therefore, the angular misalignment ( $Rb$ ) between navigation system and camera can be estimated if  $Pg$  and  $Pf$  are known from Equation 1.

The  $Pg$  vector can be derived from GPS-measured ground control points or from a high-resolution, orthorectified reference map with DEM. The  $Pg$ -related  $Pf$  vector can be located in the raw image frame. The rotation matrix  $Rc$  is a constant matrix for each DMS configuration. The rotation matrix  $Rg$  is a constant matrix for a targeted area with the converged angle difference between grid north and true north. However, the rotation matrix  $Rb$  can vary with physical and environmental conditions as well as with navigation system errors.  $Rb$  is assumed to be relatively stable and errors from physical and environmental factors are minimized if the system installation is fixed under the same condition.

In the boresight correction process, we select three to four continuous frames in multiple flight directions to cover a targeted area. Numerous ground control points, either from a high-resolution reference map or GPS surveyed points, are picked for each frame. Boresight angles are derived based on Equations 1 and 10 from *Rb* for each selected frame. Finally, boresight angles are averaged from all frames.

### 3.3.4 DMS Production Software Package

The DMS software package developed for data production is an integration of public domain software with an in-house user interface to facilitate the entire production process. The public domain software includes:

- The [Open Source Software Image Map \(OSSIM\)](#). OSSIM is a publicly available, high performance engine for photogrammetry, remote sensing, image processing, and geographical information systems.
- The [Geospatial Data Abstraction Library \(GDAL\)](#). GDAL is a translator library for raster geospatial data formats and processing. It is available under an X/MIT style Open Source license by the Open Source Geospatial Foundation.

OSSIM is written in C++ with object-orientated modules and classes. A customized sensor model is integrated in the OSSIM modules and recompiled for use in DMS production. The front end interface is developed in Perl to make the OSSIM and GDAL libraries and utilities more accessible.

Special processing notes regarding each deployment to date are provided below.

### 3.3.5 Special Processing Notes

#### **2012 Antarctica Campaign**

GeoTIFF files were produced using the RADARSAT 200 m DEM. GEOID reference is established by DEM. Sea Ice imagery referencing EGM2008 are identified with a COMMENT tag in the GeoTIFF. There are areas where DEM and aircraft converge and where DEM exceeds aircraft height. These frames were projected with zero elevation as input and altitude above terrain fixed to 250 m. Affected frames are identified with COMMENT tags in the GeoTIFF, where each data issue is explicitly noted. All output reference NSIDC Antarctic stereographic projections. There is one exception: imagery acquired over California reference standard geographic lat/long and were produced using the National Elevation Dataset 10 m DEM.

## **2012 Greenland Campaign**

Geotiff files were produced using the GLAS/ICESat 1 km Laser Altimetry DEM. GEOID reference is established by DEM. Sea ice imagery referencing EGM2008 are identified with a COMMENT tag in the geotiff. There are areas where DEM and aircraft converge and where DEM exceeds aircraft height. These frames were projected with zero elevation as input and altitude above terrain fixed to 230 m. Affected frames are identified with COMMENT tags in the geotiff, where each data issue is explicitly noted. All output references NSIDC Antarctic stereographic projections. There is one exception: imagery acquired over Virginia's East Coast reference standard geographic lat/long and were produced using the National Elevation Dataset 10 m DEM.

## **2011 Antarctica Campaign**

GeoTIFF files were produced using the RADARSAT 200 m DEM. GEOID reference is established by DEM. Sea Ice imagery referencing EGM2008 are identified with a COMMENT tag in the GeoTIFF. There are areas where DEM and aircraft converge and where DEM exceeds aircraft height. These frames were projected with zero elevation as input and altitude above terrain fixed to 230 m. Affected frames are identified with COMMENT tags in the GeoTIFF, where each data issue is explicitly noted. All output references NSIDC Antarctic stereographic projections. There is one exception: imagery acquired over Southern California reference standard geographic lat/long and were produced using the National Elevation Dataset 10m DEM.

## **2011 Greenland Campaign**

GeoTIFF files were produced using the GLAS/ICESat 1 km Laser Altimetry Digital Elevation Model of Greenland. There are areas where DEM and aircraft converge. Affected frames are identified with a COMMENT tag in the GeoTIFF. Frames where DEM exceeds aircraft height were projected with zero elevation as input. Frames where Aircraft-DEM delta was less than 65 m were projected using a 2D model.

## **2010 Antarctica Campaign**

For the 2010 Antarctica campaign only, the standard parallel for sea ice images is 70° S. The standard parallel for land ice images for this campaign is 71° S.

## 2009 Antarctica Campaign

A refined camera model was implemented, as well as enhanced boresight angles. In addition, RADARSAT 200 m DEM was used as ground reference input. A new metadata field has been embedded in each GeoTIFF referencing version differences. There are areas where DEM and aircraft converge. Affected frames are identified with an additional COMMENT tag in the GeoTIFF. Frames where the DEM exceeds aircraft height were projected with zero elevation as input. Frames where Aircraft-DEM delta was less than 65 m were projected using a 2D model. Most imagery were acquired in panchromatic mode, but all provided output is 3-banded imagery. Flights where some imagery were collected in both modes were processed as "color" as identified in the GeoTIFF embedded metadata.

### 3.3.6 Processing Steps

DMS is a commercial off the shelf camera. The time stamp in the Level-0 jpeg imagery is from the internal camera clock. The camera's intervalometer is tied to the Applanix. For the Level-1B data, a series of linear regressions is used to map out the time lag and sync the camera shutters to the nav data. That synched time is embedded into the GeoTIFF along with other metadata.

The following processing steps are performed by the data provider.

DMS geo-rectified TIFF imagery is supplied on a best effort basis. Processing steps include (1) time sync between the DMS internal clock and POS/AV, (2) definition of frame geometry to include bore-sight adjustment, lens distortion and digital elevation model (DEM) inputs, and (3) GeoTIFF production with ancillary documentation and a variety of map projection allowances.

The camera's internal clock drifts over time. Alone it cannot be used to sync to corresponding navigation data. Thus an intervalometer is used to trigger each shutter function. This is captured via a TTL pulse as an Applanix event.

The cameras are calibrated prior to each deployment using the Photometrix Australis package. The calibration provides focal length, principal point, terms of radial distortion, as well as coefficients of de-centering distortion.

Boresight angles are calculated using High Resolution Ortho-rectified images (HRO) or other precise surveys and best available elevation data. Three or four continuous frames from multiple



flight headings are used to derive the alignment differences between the camera's focal plane and the POS/AV. Ten to twelve broadly spaced control points are selected for each frame.

Once the boresight and lens distortion corrections are applied, a 3D ray trace is performed to generate the final GeoTIFF. The quality and resolution of DEM is a key factor in geo-location accuracy. The distance between the focal plane and ground determines the footprint of each frame. Over varying terrain the frame-edge location will be severely degraded if DEM resolution significantly differs from pixel geometry.

There were some targets where the available DEM exceeded aircraft height or where the DEM converged towards aircraft altitude. Spring 2013 also had a single flight with a polar crossing. Any frame requiring additional processing has extra embedded metadata.

### 3.3.7 Version History

**Version 1.1:** On 12 April 2011, re-processed 2009 Antarctica DMS data became available and replaced the previous version. The 2009 Antarctica DMS data required re-processing because the data were projected using the SRTMplus Digital Elevation Model (DEM). This DEM references the sea floor for all non-terrestrial locations. In addition, during re-processing, a more refined boresight model was employed which provides a more accurate attitude reference. See the Special Processing Notes section for more on the 2009 Antarctica campaign.

**Version 1.2:** On 18 March 2013, 9505 frames were replaced with reprocessed data for the 11 April 2012 East Glaciers-1 flight. If you downloaded the 11 April 2012 files prior to 18 March 2013, it is recommended that you re-download them. The original frames from the flight's Level-1B files were smaller and of lower resolution than images earlier in the flight at the same aircraft height above ground level (AGL) of 470-480 m. The affected 11 April 2012 frames include: 09186 to 09189, 09243 to 09268, 09270 to 09368, 09376 to 09385, 09391 to 10428, 10488 to 10733, and 10833 to 18914. See the File Naming Convention section for reference to frame numbers.

**Version 1.3:** The geolocation for one flight from the Spring 2018 mission was refined. The reprocessing applies only to the last 1092 frames from 07 April 2018.

### 3.3.8 Errors and Limitations

**2015 Antarctica:** during the 2015 Antarctica campaign the aircraft window had to be repaired in the field. The replacement window was green and tinted the imagery. Affected frames include an additional COMMENT in the GeoTIFF file describing the issue.

## 4 REFERENCES AND RELATED PUBLICATIONS

Farr, T. G., et al. 2007. The Shuttle Radar Topography Mission, *Rev. Geophys.*, 45:RG2004, doi:10.1029/2005RG000183.

### 4.1 Related Data Collections

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- [ASTER Global Digital Elevation Model \(GDEM\)](#)
- [GLAS/ICESat 1km Laser Altimetry Digital Elevation Model of Greenland](#)
- [IceBridge DMS L0 Raw Imagery](#)
- [IceBridge DMS L3 Photogrammetric DEM](#)
- [IceBridge CAMBOT L1B Geolocated Images](#)
- [National Elevation Dataset 1/3 Arc-Second \(NED 1/3\)](#)
- [Radarsat Antarctic Mapping Project Digital Elevation Model Version 2](#)

### 4.2 Related Websites

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- [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](#)

## 5 DOCUMENT INFORMATION

### 5.1 Publication Date

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15 November 2012

## 5.2 Date Last Updated

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06 June 2018