Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness, Version 1

USER GUIDE

How to Cite These Data

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

Thomas, R. and M. Studinger. 2010. *Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/6C6WA3R918HJ. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/BLATM2

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

The Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness data files are in fixed-width, space-delimited ASCII text format.

Each data file is paired with an associated XML file. The XML files contain location, platform, and instrument metadata.

1.2 File and Directory Structure

Data files are available on the FTP site in the ftp://n5eil01u.ecs.nsidc.org/SAN2/PRE_OIB/BLATM2.001/ directory. Files are organized into folders by year, month, and day, for example: /1993.06.23/ through /2008.10.30/.

1.3 File Naming Convention

Icessn data files are named according to the following convention and as described in Table 1:

Examples:

```
BLATM2_930623_115606_smooth_nadir2seg
BLATM2_081030_191355_smooth_nadir3seg_50pt
```

```
BLATM2_YYMMDD_HHMMSS_smooth_nadir3seg_50pt
```

Table 1. File Naming Convention

Variable	Description
BLATM2	Short name for Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
YY	two-digit year
MM	two-digit month
DD	two-digit day
HH	start time: two-digit hours
MM	start time: two-digit minutes
SS	start time: two-digit seconds
smooth	alongtrack values smoothed in icessn process
nadir3seg	nadir block plus 3 off-nadir blocks per time stamp
50pt	minimum of 50 points needed to output a block

XML metadata file names use an abbreviated form of the above convention, with an .xml extension, e.g. `BLATM2_930623_115606.xml`.

A summary file is included for each data file. Summary files contain information for start time, stop time, swath width, segments, output interval, smoothing interval, minimum data points, comments and icessn and qfit processing header information.

Summary files are named according to the following conventions and as described in Table 2:

```
Examples:
BLATM2_081030_191355_icessn_summary_50pt
BLATM2_930623_115606_icessn_summary
```

```
BLATM2_ YYMMDD_HHMMSS_icessn_summary_50pt
```

Table 2. Summary File Naming Convention

Variable	Description
BLATM2	Short name for Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
YY	two-digit year
MM	two-digit month
DD	two-digit day
HH	start time: two-digit hours
MM	start time: two-digit minutes
SS	start time: two-digit seconds
icessn	format of smoothed data and reduced data volume
summary	summary file for corresponding icessn file
50pt	minimum of 50 points needed to output a block

1.4 File Size

Elevation measurement files range from 4 KB to 5 MB.

Summary files range from 6 KB to 11 KB.

XML files range from 4 KB to 23 KB.

1.5 Volume

The entire data set is approximately 4.8 GB.

1.6 Spatial Coverage

Spatial coverage for this data includes the Arctic, Antarctica, and surrounding ocean areas.

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

1.6.1 Spatial Resolution

The ATM surface elevation measurements have been re-sampled at a variable along-track time interval, typically averaging 0.5 seconds worth of data and creating an output record every 0.25 seconds, which at aircraft survey speed is a distance along the flight track of approximately 30 meters. The distance can vary with aircraft speed. Each set of along-track records contains a fixed 80 m across-track nadir platelet as well as three or five additional platelets that together span the entire swath of the ATM scan.

1.6.2 Projection and Grid Description

No projection. Data are georeferenced to WGS-84.

1.7 Temporal Information

1.7.1 Temporal Coverage

These data were collected from 23 June 1993 to 30 October 2008.

1.7.2 Temporal Resolution

The data were collected during non-continuous sequences of flights during the time periods noted above under Temporal Coverage.

1.8 Parameter or Variable

The ATM measures topography as a sequence of points scanned in a swath along the aircraft flight track. The icessn program condenses the ATM Level-1B Qfit measurements by fitting a plane to blocks of points selected at regular intervals along track and several across track.

The Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness data set includes south to north slope and west to east slope measurements.

1.8.1 Parameter Description

The icessn data contains 11 columns per record as defined in Table 3. **Note:** Column numbers and descriptive headings are not included in the data files.

Table 3. Parameter Description, Units, and Range

Column	Description	Units	Range
1	Time at which the aircraft passed the mid-point of the block.	Seconds of the day in GPS time. As of 01 January 2009 GPS time = UTC + 15 seconds.	0 to 86400
2	Latitude of the center of the block.	Degrees	-90.0 to +90.0
3	East longitude of the center of the block.	Degrees	0.0 to 360.0
4	Height above WGS84 ellipsoid of the center of the block.	Meters	-100.0 to 10000.0
5	South to North slope of the block.	Dimensionless	any real value
6	West to East slope of the block.	Dimensionless	any real value
7	RMS fit of the ATM data to the plane.	Centimeters	Greater than 0.0
8	Number of points used in estimating the plane parameters.	Count	Greater than 0
9	Number of points removed in estimating the plane parameters.	Count	Greater than or equal to 0

10	Distance of the center of the block from the centerline of the aircraft trajectory (starboard = positive, port = negative).	Meters	real valued
11	Track identifier (numbered 1...n, starboard to port, and 0 = nadir).	Number	0, 1, 2, …

1.8.2 Sample Data Record

Below is an excerpt from data file `BLATM2_081030_152251_smooth_nadir3seg_50pt`. The fields in each record correspond to the columns described in Table 3.

```
 55340.5561 -67.819832 292.680328   70.8787   .16700554
.09785142  117.31    55    3  270. 1
 55340.8061 -67.820148 292.679901   62.2601   .17769073
.08851736   32.22    56    3  288. 1
 55341.0561 -67.820460 292.680048   54.1891   .20294642
.06927341   31.43    61    0  283. 1
 55341.3061 -67.820772 292.680066   46.0538   .19831565
.05845884   22.52    73    1  283. 1
 55341.8061 -67.821401 292.679437   27.5681   .22137341
.01654823   50.25    56    1  310. 1
 55470.5561 -67.976465 292.661510    7.8502  -.00022986
.00116313   16.29    67    0  211. 1
 55470.5561 -67.976613 292.666107    7.8749  -.00296106
-.00041221   14.24    89    0   19. 2
 55470.5561 -67.976761 292.670703    7.7612  -.00122355
-.00001858   11.08    52    1 -173. 3
 55470.8061 -67.976747 292.661321    7.8488  -.00076551
.00070150   17.16   125    0  216. 1
 55470.8061 -67.976890 292.665699    7.8759  -.00001190
.00032220   15.77   104    0   33. 2
```

Figure 1. Sample data file.

2 SOFTWARE AND TOOLS

2.1 Software and Tools

NSIDC provides a MATLAB reader that reads ATM icessn data files from the Operation IceBridge Airborne Topographic Mapper instrument.

3 DATA ACQUISITION AND PROCESSING

3.1 Data Acquisition Methods

A laser altimeter measures range from the instrument to a target by measuring the elapsed time between emission of a laser pulse and detection of laser energy reflected by the target surface. Range to the target is calculated as half the elapsed emission/return time multiplied by the speed of light. Target range is converted to geographic position by integration with platform GPS and attitude or Inertial Measurement Unit (IMU) information.

The ATM deployments included two lidar systems whenever the aircraft platform would allow. The redundancy reduced the risk of hardware failures and provided a means of validating modifications to the lidar. The data were processed from both instruments up to a point, but then efforts concentrated on refining and delivering data from a single lidar. Each campaign therefore has a "primary" lidar, and sometimes a "secondary" lidar. This data set contains only data from the primary lidar.

The ATM instrument package includes suites of LIDAR, GPS and attitude measurement subsystems. The instrument package is installed onboard the aircraft platform and calibrated during ground testing procedures. Installation mounting offsets, the distances between GPS and attitude sensors and the ATM LIDARs, are measured using surveying equipment. One or more ground survey targets, usually aircraft parking ramps, are selected and surveyed on the ground using differential GPS techniques. Prior to missions, one or more GPS ground stations are established by acquiring low rate GPS data over long time spans. Approximately one hour prior to missions both the GPS ground station and aircraft systems begin data acquisition. During the aircraft flight, the ATM instrument suite acquires LIDAR, GPS and attitude sensor data over selected targets, including several passes at differing altitudes over the selected ground survey calibration sites. The aircraft and ground systems continue to acquire data one hour post-mission. Instrument parameters estimated from the surveys of calibration sites are used for post-flight calculation of laser footprint locations. These parameters are later refined using inter-comparison and analysis of ATM data where flight lines cross or overlap.

3.2 Derivation Techniques and Algorithms

The ATM surface elevation measurements have been re-sampled into an icessn format which smooths the data and reduces the data volume. Users desiring unsampled data should use the Pre-IceBridge ATM L1B Qfit Elevation and Return Strength data.

The fundamental form of ATM topography data is a sequence of laser footprint locations acquired in a swath along the aircraft flight track. The icessn program condenses the ATM surface elevation measurements by fitting a plane to blocks of points selected at regular intervals along track and several across track. The block size and spacing can be specified, but a few typical values are used. The along-track distance smoothed is the distance which the aircraft moves in a fixed interval, 0.5 seconds for P-3 and DC8 aircraft, and 1.0 seconds for DHC-6 Twin-Otter. The data output interval is half of the smoothing interval so that there is 50 percent overlap between successively smoothed blocks. For each along-track position/time, there are multiple blocks spaced evenly across-track to span the swath width. Typically the number of blocks is five for the T3 scanner and three for the T2 scanner. There is an additional block located at aircraft nadir with a width typically set to 80 m. If a single profile is desired, the nadir profile can be selected from the full data set.

The south to north slopes and the west to east slopes estimated are used to estimate surface elevations at points other than the center point through the use of the following algorithm shown in Equation 1 and described in Table 4:

ht(phi,lambda) = ht(phi0,lambda0) + SNslope * (phi - phi0) * 6378137 * pi/180 + WEslope * (lambda - lambda0) * cos(phi0) * 6378137 * pi/180	**(Equation 1)**

Table 4. Surface Elevations Estimate Algorithm Variables

Variables	Description
ht	height in meters at coordinates (phi, lambda)
phi	latitude at location of interest in radians (spherical coordinate angle from positive z-axis to surface elevation point)
lambda	longitude at location of interest in radians
phi0	latitude at center of tile in radians
6378137	WGS84 ellipsoid semi-major axis in meters
lambda0	longitude at center of tile in radians
SNslope	south/north slope of the tile
WEslope	west/east slope of the tile

Note: The multiple across-track planes at a given along-track position will have the same time tag.

3.2.1 Processing Steps

The following processing steps are performed by the data provider.

1. Preliminary processing of ATM LIDAR data through the cvalid program, applying calibration factors to convert time of flight to range, scan pointing angles and interpolated attitude to each LIDAR measurement.

2. Processing of GPS data into aircraft trajectory files using double-differenced dual-frequency carrier phase-tracking.

3. Processing of the cvalid program output combined with the GPS trajectory data through the qfit program, resulting in an output file containing a surface elevation (ellipsoid height) and a geographic location in latitude and east longitude with other ancillary parameters.

4. Processing of the qfit output through the icessn program which averages the qfit surface elevation data into a small number of blocks or surface planes.

3.2.2 Version History

On July 19, 2012, Pre-IceBridge L2 ATM data files for dates 27 June 2008 through 02 August 2008 were replaced by Version 01.1. The difference between V01 and V01.1 relates to the limit imposed on the GPS PDOP. The arrangement of the GPS satellites at any given time affects the theoretical precision of the estimated aircraft position. A figure of merit of this impact is the Positional Dilution of Precision (PDOP). Word 10 of the 12-word qfit data format contains the PDOP value multiplied x10. Lower PDOP implies greater precision. The V01 processing eliminated any data with a PDOP greater than 9, possibly causing some gaps in the data coverage. Some applications of the data, with less stringent accuracy requirement, might benefit from inclusion of less accurate data rather than having no data in these gaps. The V01.1 processing allows PDOP up to 20. The qfit data can be filtered using word 10 to select a desired PDOP cutoff. The provided icessn data are derived from qfit data with a PDOP of 20 or lower.

3.2.3 Sensor or Instrument Description

The ATM is an airborne LIDAR instrument used by NASA for observing the Earth's topography for several scientific applications, foremost of which is the measurement of changing Arctic and Antarctic icecaps and glaciers. The ATM instrument is a scanning airborne laser that measures surface elevation of the ice by timing laser pulses transmitted from the aircraft, reflected from the ground and returning to the aircraft. This laser pulse time-of-flight information is used to derive surface elevation measurements by combining measurement of the scan pointing angle, precise GPS trajectories and aircraft attitude information. The ATM instrument measures topography as a sequence of points scanned in a swath along the aircraft flight track. The sampling frequency for the ATM is 5 kHz.

The ATM instruments are developed and maintained at NASA's Wallops Flight Facility (WFF) in Virginia, USA. During Operation IceBridge, the ATM has been installed aboard the NASA P3-B aircraft based at WFF, or the NASA DC8 aircraft based at Dryden Air Force Base in Palmdale, California. During previous campaigns, the ATM has flown aboard other P-3 aircraft, several de Havilland Twin Otters (DHC-6), and a C-130. The ATM has been used for surveys flown in Greenland nearly every year since 1993. Other uses have included measurement of sea ice, verification of satellite radar and laser altimeters, and measurement of sea-surface elevation and ocean wave characteristics. The ATM often flies in conjunction with a variety of other instruments and has been participating in NASA's Operation IceBridge since 2009.

4 REFERENCES AND RELATED PUBLICATIONS

Kwok, R., G. F. Cunningham, S. S. Manizade, and W. B. Krabill. 2012. Arctic sea ice freeboard from IceBridge acquisitions in 2009: Estimates and comparisons with ICESat. *Journal of Geophysical Research* 117: C02018. doi:10.5067/6C6WA3R918HJ.

4.1 Related Data Collections

- Antarctic 5-km Digital Elevation Model from ERS-1 Altimetry
- GLAS/ICESat 500 m Laser Altimetry Digital Elevation Model of Antarctica
- GLAS/ICESat L1 and L2 Global Altimetry Data
- IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
- Trajectory Maps - ATM
- USGS United States Antarctic Resource Center LIDAR High-resolution DEM Final DATA Downloads (DEMs created from ATM Data)

4.2 Related Websites

- Airborne Topographic Mapper Web site at NASA Wallops Flight Facility (http://atm.wff.nasa.gov/).
- Description of DEM Generation, Dry Valleys, Antarctica (http://rsl.geology.buffalo.edu/research/DEM/home.htm).
- IceBridge Data Web site at NSIDC http://nsidc.org/data/icebridge/index.html
- IceBridge Web site at NASA (http://www.nasa.gov/mission_pages/icebridge/index.html).
- ICESat/GLAS Web site at NASA Wallops Flight Facility (http://glas.wff.nasa.gov/).
- ICESat/GLAS Web site at NSIDC (http://nsidc.org/daac/projects/lidar/glas.html).

5 CONTACTS AND ACKNOWLEDGMENTS

5.1 Contacts

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5.2 Acknowledgments

The ATM project team would like to acknowledge the dedicated NASA P3 and DC8 flight crews, whose efforts allowed the safe and efficient collection of this data over some of the most isolated and extreme regions on this planet. The 2002, 2004, and 2008 Antarctic campaigns were made possible through a collaboration between NASA/ATM, the Chilean Centro de Estudios Científicos (Center for Scientific Studies) aka CECS, and the Armada de Chile (Chilean Navy).

6 DOCUMENT INFORMATION

6.1 Publication Date

11 August 2016