IceBridge ATM L1B Qfit Elevation and Return Strength, Version 1

USER GUIDE

How to Cite These Data

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

Studinger, M. 2010, updated 2013. *IceBridge ATM L1B Qfit Elevation and Return Strength, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/DZYN0SKIG6FB. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ILATM1B

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

The fundamental form of the ATM topography data is a sequence of laser footprint locations acquired in a swath along the aircraft flight track. The data are stored in qfit output files organized as 32 bit, 4 byte, binary integer words scaled to retain the precision of the measurements. Surveys from 2009 and Spring 2010 are in big-endian format. Starting with the 2010 Antarctica campaign, the format of the qfit data files have been changed to little-endian binary. In the past, the .qi files were output in big-endian byte order. The qfit files are now in little-endian byte order. The format of the file content has not changed; only the 'endianness' of the files has changed. The beginning of each file contains a header of one or more records followed by a data segment in which there is one record per laser shot.

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

For more information, see ReadMe.qfit.txt.

Note: For sub-sampled ATM data, see the IceBridge ATM L2 Icessn Elevation, Slope, and Roughness data set.

1.2 File Naming Convention

Qfit files are named according to the following conventions and as described in Table 1:

`ILATM1B_20120428_111511.ATM4BT4.qi`

`ILATM1B_YYYYMMDD_HHMMSS.ATM4XTn.qi`

Where:

Table 1. File Naming Convention

Variable	Description
ILATM1B	File name prefix indicating ATM L1B data
YYYY	Four-digit year of survey
MM	Two-digit month of survey
DD	Two-digit day of survey
HH	Two-digit hours, beginning of file time

Variable	Description
MM	Two-digit minutes, beginning of file time
SS	Two-digit seconds, beginning of file time
ATM4X	Airborne Topographic Mapper instrument identification, e.g. atm4c or ATM4B
Tn	Scan angle. T2 = 15-degree off-nadir scan angle. T3 = 23-degree off-nadir scan angle. T4 = 30-degree off-nadir scan angle.
.qi	indicates qfit output file

XML metadata file names use the above convention, with a .xml extension.

1.3 File Size

Qfit elevation measurement files range from approximately 398 KB 54 MB.

XML files range from approximately 5 KB 12 KB.

1.4 Volume

The entire data set is approximately 553 GB.

1.5 Spatial Coverage

Spatial coverage for the IceBridge ATM campaigns includes the Arctic, Greenland, Antarctica, and surrounding ocean areas. In effect, this represents the coverage noted below.

Arctic / 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

1.5.1 Spatial Resolution

The ATM qfit surface elevation measurements have been acquired from a conically scanning LIDAR system. Coupled with the motion of the aircraft in flight, the resulting array of laser spot measurements is a tight spiral of elevation points. The surface elevation measurements generally consist of a pattern of overlapping roughly elliptical patterns on the surveyed surface, forming a swath of measurements along the path of the aircraft. Resolution varies with the altitude flown and the scanner configuration for the LIDAR. At a typical altitude of 500 m above ground level, a laser pulse rate of 5 kHz, and a scan width of 22.5 degrees off-nadir, the average point density is one laser shot per 10 m^2 within the swath.

1.5.2 Projection and Grid Description

Data are given in geographic latitude and longitude coordinates. Data coordinates are referenced to the WGS84 ellipsoid. Reference frame is prescribed by the International Terrestrial Reference Frame (ITRF) convention in use at the time of the surveys. For more on the reference frame, see the ITRF 2008 specification Web site.

1.6 Temporal Coverage

These data were collected as part of Operation IceBridge funded campaigns beginning 31 March 2009 to 08 November 2012.

1.6.1 Temporal Resolution

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

The sampling frequency for the Airborne Topographic Mapper is 5 kHz.

1.7 Parameter or Variable

The ATM L1B Qfit Elevation and Return Strength data set includes glacier, ice sheet, and sea ice elevation measurements, and relative transmitted and return reflectance.

The ATM qfit times are rounded to 0.001 seconds. The ATM instrument operates at a sampling rate of 5 kHz. When rounding to 0.001 seconds, five points will appear with the same time stamp.

1.7.1 Parameter Description

Parameters contained in qfit ATM data files are described in Table 2. Column numbers 1 to 12 in Table 2 represent columns left to right in the data. Columns are not numbered in the data files.

Table 2. MATLAB File Parameter Description

Column	Description	Units with Scale Factor	Range
1	Relative Time measured from start of file	Seconds 10^{-3}	Greater than 0
2	Laser Spot Latitude	Degrees 10^{-6}	-90.0 to 90.0
3	Laser Spot East Longitude	Degrees 10^{-6}	0.0 to 360.0
4	Elevation of the laser spot above ellipsoid	Meters 10^{-3}	any real value
5	Start Pulse Signal Strength (relative)	Dimensionless relative values (or data numbers, DN)	positive integer value
6	Reflected Laser Signal Strength (relative)	Dimensionless relative values (or data numbers, DN)	positive integer value
7	Scan Azimuth	Degrees 10^{-3}	0.0 to 360.0
8	Pitch	Degrees 10^{-3}	-90.0 to +90.0
9	Roll	Degrees 10^{-3}	-90.0 to +90.0
10	GPS Dilution of Precision (PDOP) times 10	Dimensionless	Greater than 0
11	Laser received pulse width at half height, number of digitizer samples at 0.5 nanosecond per sample.	Count	Greater than 0
12	GPS time packed, example: 153320100 = 15 hours 33 minutes 20 seconds 100 milliseconds.	Seconds of the day in GPS time. As of 01 January 2009 GPS time = UTC + 15 seconds.	000000000 to 235959999

1.7.2 Sample Data Record

Figure 1 is an ASCII format excerpt of the `ILATM1B_20091030_212220.atm4cT3.qi` data file converted from binary. The 12 fields in each record correspond to the columns shown in Table 2.

```
# REL_TIME,LATITUDE,LONGITUDE,ELEVATION,strt_pulse_sigstr,ref_sigstr,azi,pitch,roll,GPS_dil_prec,pulse_width,TIME-HHMMSS
  0.013000 -62.2729630 -53.9766270   22.643    1364   241   240      1.726       0.206     22.0        5.0 212236.013000
  0.014000 -62.2729780 -53.9766830   22.760    1073   293   243      1.726       0.205     22.0        5.0 212236.014000
  0.014000 -62.2729850 -53.9767100   22.589    1206   695   244      1.727       0.205     22.0        6.0 212236.014000
  0.014000 -62.2729920 -53.9767390   22.433    1498   531   246      1.727       0.205     22.0        7.0 212236.014000
  0.014000 -62.2729980 -53.9767680   22.671    1063   410   247      1.727       0.205     22.0        7.0 212236.014000
  0.015000 -62.2730230 -53.9768890   22.610    1205  1399   253      1.728       0.204     22.0        7.0 212236.015000
  0.017000 -62.2730720 -53.9772140   22.333    1217   662   267      1.729       0.203     22.0        6.0 212236.017000
  0.028000 -62.2727950 -53.9788780   21.783    1224   336   346      1.734       0.198     22.0        7.0 212236.028000
  0.036000 -62.2722780 -53.9785740   23.091    1079   285    41      1.732       0.194     22.0        6.0 212236.036000
```

Figure 1. Sample Data Record (`ILATM1B_20091030_212220.atm4cT3.qi`)

2 SOFTWARE AND TOOLS

The elevation measurement files contain qfit binary data. The qfit format was developed for use at Wallops Flight Facility (WFF). NSIDC provides a C qfit data reader that reads a binary qfit file and outputs a text file, an IDL qfit data reader that reads qfit data into an IDL array, and a MATLAB reader that reads qfit data files. LAStools can read and write NASA ATM qfit format.

3 DATA ACQUISITION AND PROCESSING

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.

3.1 Data Acquisition Methods

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

Each ATM surface elevation measurement corresponds to one laser pulse. The measurements have not been re-sampled. The transmitted laser pulse and the received backscatter pulse from the ground surface are photodetected and captured by a waveform digitizer. Post-flight processing of the waveforms yields the time of flight between transmitted and received signals. This time of flight value is converted to a distance compensated for speed of light through atmosphere. GPS data is processed post-flight to yield the position of the aircraft at 0.5 second intervals. The scan azimuth of the LIDAR scanner mirror together with the aircraft attitude determine the pointing angle of the LIDAR. Aircraft position, pointing angle of the LIDAR, and range measured by the LIDAR are used to compute position of laser footprint on the ground.

3.2.1 Processing Steps

The processing program, qfit, combines airborne laser ranging data and aircraft attitude from the Inertial Navigation System (INS) with positioning information from a processed kinematic differential Global Positioning System (GPS) trajectory.

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 interpolate attitude to each LIDAR measurement.
2. Processing of GPS data into aircraft trajectory files using double-differenced dual-frequency carrier phase-tracking.
3. Determination of all biases and offsets: heading, pitch, roll, ATM-GPS [x,y,z] offset, scanner angles, range bias.
4. Processing of the LIDAR and GPS data with all biases and offsets through the qfit program, resulting in output files containing a surface elevation (ellipsoid height) and a geographic location in latitude and east longitude, with ancillary parameters noted in Table 3.

3.2.2 Errors and Limitations

During collection of IceBridge ATM Greenland data on 12 and 13 April 2010, hydraulic oil progressively leaked from the forward landing gear on the DC8 aircraft. The oil was blown back along the bottom of the fuselage and across the nadir window through which the ATM was transmitting and receiving the laser signal. The ATM signal was attenuated, and data in part of the scan is missing as a result. The problem developed during the flight and worsened through time. The ATM still acquired more than half of the shots throughout the scan. The net effect of this problem is to decrease the number of shot returns logged, the same as if the laser power was reduced. To the user this will appear as a reduced point density on the ground. This issue will not affect the accuracy of the data. In the Antarctic 2010 campaign, fuel leakage degraded the signal in a similar fashion.

The April 28, 2012 flight traversed the notoriously turbulent regions of Greenland's southeast glaciers. During the flight, two planned glaciers were skipped due to concern about expected severe turbulence. The survey data spans roughly 11:15 to 18:20 UTC. On the approach to Ikerssuaq glacier at 16:56:19.5 (GPST=60994.5 secs), both the ATM T3 and T4 instruments quit recording data within 0.1 second of each other. T3 resumed at 16:57:05.3 whereas T4 did not resume for the rest of that day's flight. Following this event, the flight followed the Ikerssuaq flow line, then traversed straight west across the icesheet back to the Kangerlussuaq airport. The data gap spans 46 seconds, from the fjord up to about 500 m elevation on the Ikerssuaq glacier. The T4 data quit during the creation of the file 20120428_165532.ATM4BT4.F1.qi. The T4 data is being supplemented by the these narrow swath files of T3 data from the latter part of the survey:

```
20120428_165449.atm4cT3.F1.qi
20120428_170030.atm4cT3.F1.qi
20120428_170524.atm4cT3.F1.qi
20120428_171019.atm4cT3.F1.qi
20120428_171514.atm4cT3.F1.qi
20120428_172008.atm4cT3.F1.qi
20120428_172503.atm4cT3.F1.qi
20120428_172957.atm4cT3.F1.qi
20120428_173452.atm4cT3.F1.qi
20120428_173947.atm4cT3.F1.qi
20120428_180815.atm4cT3.F1.qi
20120428_181219.atm4cT3.F1.qi
20120428_181619.atm4cT3.F1.qi
```

The above files can be found with the IceBridge Narrow Swath ATM L1B Qfit Elevation and Return Strength 2012 Greenland data. For details on the ATM 4BT3 and 4BT4 instruments, see the Sensor Or Instrument Description section below, and the IceBridge Narrow Swath ATM L1B Qfit Elevation and Return Strength data set documentation.

3.3 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 measures topography as a sequence of points conically scanned in a swath along the aircraft flight track at rates up to 5000 measurements per second.

The ATM instruments are developed and maintained at NASA's 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. See also Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness. The ATM often flies in conjunction with a variety of other instruments and has been participating in NASA's Operation IceBridge since 2009.

The ATM project normally installs and operates two lidars on the aircraft platform. From 2009 to 2010, data were provided to NSIDC only from the ATM 4B2T that collects wide scan lidar data. In 2011, a new ATM transceiver scanner assembly designated as ATM 4BT4 replaced the ATM 4BT2. The second lidar system on the aircraft, designated ATM 4CT3, was operated prior to 2011 as a backup to the ATM 4BT2 lidar instrument, or was modified to test alternate lidar system improvements. In 2011, ATM 4CT3 laser power was reduced and data were collected using the narrow swath scanner. Data from the 4CT3, provided for sea ice missions only, are found in the IceBridge Narrow Swath ATM L1B Qfit Elevation and Return Strength data set.

Table 3 provides information on ATM transceivers used during IceBridge missions and the resultant filename designations.

Table 3. ATM System Designations by IceBridge Campaign

Year	Campaign	Wide ATM System* (xx) = Full Scan Angle (degrees)	Narrow ATM System* (x) = Full Scan Angle (degrees)
2009	Greenland	4BT2 (30)	n/a
2009	Antarctica	4CT3 (44)	n/a
2010	Greenland (DC-8)	4CT3 (44)	n/a
2010	Greenland (P-3)	4BT2 (30)	n/a
2010	Antarctica	4BT2 (30)	n/a
2011	Greenland	4BT4 (30)	4CT3 (5)**
2011	Antarctica	4BT2 (30)	4CT3 (5)**
2012	Greenland	4BT4 (30)	4CT3 (5)**
2012	Antarctica	4BT4 (30)	4CT3 (5)**
2013	Greenland	4BT4 (30)	4CT3 (5)**

* The ATM system designation is noted in the filename for each data file.

** Data are provided for sea ice missions only.

Note: Continuous Airborne Mapping By Optical Translator (CAMBOT) images and .cam files containing aircraft position and attitude data corresponding to the ATM qfit data can be found in the IceBridge CAMBOT L1B Geolocated Images data set.

4 REFERENCES AND RELATED PUBLICATIONS

Brunt, K. M., Hawley, R. L., Lutz, E. R., Studinger, M., Sonntag, J. G., Hofton, M. A., Andrews, L. C., and Neumann, T. A. 2017. Assessment of NASA airborne laser altimetry data using ground-based GPS data near Summit Station, Greenland, *The Cryosphere*, 11:681-692. doi:10.5194/tc-11-681-2017.

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:10.1029/2011JC007654.

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 Narrow Swath ATM L1B Qfit Elevation and Return Strength
- IceBridge ATM L2 Icessn Elevation, Slope, and Roughness

- Trajectory Maps - ATM
- Pre-IceBridge ATM L1B Qfit Elevation and Return Strength
- Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
- 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
- Description of ATM QFIT Output Data (revised 2009-feb-13).
- Description of DEM Generation, Dry Valleys, Antarctica
- IceBridge Data Web site at NSIDC
- IceBridge Web site at NASA
- ICESat/GLAS Web site at NASA Wallops Flight Facility
- ICESat/GLAS Web site at NSIDC
- ITRF 2008 Specification Web site

4.3 Contacts and Acknowledgments

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4.3.1 Acknowledgments

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5 DOCUMENT INFORMATION

5.1 Publication Date

10 January 2011

5.2 Date Last Updated

08 May 2013