IceBridge ATM L2 Icessn Elevation, Slope, and Roughness, Version 2

USER GUIDE

How to Cite These Data

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

Studinger, M. 2014, updated 2020. *IceBridge ATM L2 Icessn Elevation, Slope, and Roughness, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/CPRXXK3F39RV. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ILATM2

NSIDC National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

NOTE: See the Errors and Limitations section for information on narrow-swath ATM data substituted for wide-swath data during the 14 April 2015 campaign.

1.1 Format

The data files are in CSV (.csv) format.

The header of each CSV data file contains information for: Input filename, Number of segments, Nadir block width, Output interval, Smoothing interval, Trajectory file used, International Terrestrial Reference Frame. Also included are headings for each field in the data file: UTC_Seconds_Of_Day, Latitude(deg), Longitude(deg), WGS84_Ellipsoid_Height(m), South-to-North_Slope, West-to-East_Slope, RMS_Fit(cm), Number_Of_ATM_Measurments_Used, Number_Of_ATM_Measurements_Removed, Distance_Of_Block_To_The_Right_Of_Aircraft(m), Track_Identifier

Each data file is paired with an associated XML file, which contains additional metadata.

1.2 File Naming Convention

Example file names:

`ILATM2_20130424_183845_smooth_nadir3seg_50pt.csv`

`ILATM2_20130424_183845_smooth_nadir3seg_50pt.csv.xml`

Files are named according to the following convention, which is described in Table 1:

`ILATM2_YYYYMMDD_HHMMSS_smooth_nadir3seg_50pt.xxx`

Table 1. File Naming Convention

Variable	Description
ILATM2	Data set ID
YYYYMMDD	Year, month, and day of survey
HHMMSS	Hours, minutes, and seconds (beginning of file time)
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
.xxx	Indicates file type: `.csv` = CSV data file `.xml` = XML metadata file

1.3 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

Antarctica:
Southernmost Latitude: 90° S
Northernmost Latitude: 53° S
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

1.3.1 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. This data set contains data from one of two different ATM sensors depending on the year the data were collected. The ATM 15° off-nadir scanner (T2) has an off-nadir scan angle of 15 degrees and these data were smoothed into three across-track platelets. The ATM 23° off-nadir scanner (T3) has an off-nadir scan angle of 23° and is smoothed into five across-track platelets. The across-track widths of these three to five additional platelets can vary with aircraft altitude.

1.3.2 Projection and Grid Description

No projection. Data are georeferenced to WGS-84.

1.4 Temporal Coverage

31 March 2009 to 20 November 2019

1.4.1 Temporal Resolution

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

1.5 Parameter or Variable

This data set includes glacier, ice sheet, and sea ice elevation measurements, as well as slope measurements, and roughness measurements.

1.5.1 Parameter Description

Data files contain parameters as defined in Table 2.

Table 2. Parameters, Units, and Range

Parameter	Description	Units	Range
UTC_Seconds_Of_Day	Time at which the aircraft passed the mid-point of the block.	Seconds of the day in UTC	0 to 86400
Latitude	Latitude of the center of the block.	Degrees	-90.0 to +90.0
Longitude	East longitude of the center of the block.	Degrees	0.0 to 360.0
WGS84_Ellipsoid_Height	Height above WGS84 ellipsoid of the center of the block.	Meters	-100.0 to 10000.0
South-to-North_Slope	South to North slope of the block.	Dimensionless	any real value
West-to-East_Slope	West to East slope of the block.	Dimensionless	any real value
RMS_Fit	RMS fit of the ATM data to the plane.	Centimeters	Greater than 0.0

Parameter	Description	Units	Range
Number_Of_ATM_Measurments_Used	Number of points used in estimating the plane parameters.	Count	Greater than 0
Number_Of_ATM_Measurements_Removed	Number of points removed in estimating the plane parameters.	Count	Greater than or equal to 0
Distance_Of_Block_To_The_Right_Of_Aircraft	Distance of the center of the block from the centerline of the aircraft trajectory (starboard = positive, port = negative).	Meters	real valued
Track_Identifier	Track identifier (numbered 1...n, starboard to port, and 0 = nadir).	Number	0, 1, 2, 3, …

1.5.2 Sample Data Record

Figure 1 shows an excerpt from file `ILATM2_20130424_183845_smooth_nadir3seg_50pt.csv`.

```
# Filename: ILATM2_V01_20130424_183845_smooth_nadir3seg_50pt.csv
# Input filename: ILATM1B_V01_20130424_183845.ATM4BT4.qi
# Number of segments: 3
# Nadir block width: 80.0m
# Output interval: 0.25sec
# Smoothing interval: 0.5sec
# Trajectory file used: 130424_aa_l12_jgs_itrf08_29may13_b898
# International Terrestrial Reference Frame: ITRF08
#
# UTC_Seconds_Of_Day, Latitude(deg), Longitude(deg), WGS84_Ellipsoid_Height(m), South-to-North_Slope,
West-to-East_Slope, RMS_Fit(cm), Number_Of_ATM_Measurments_Used, Number_Of_ATM_Measurements_Removed,
Distance_Of_Block_To_The_Right_Of_Aircraft(m), Track_Identifier
67148.25, 76.579540, 290.213746, 339.2755, -0.0418124, 0.0016997, 8.05, 57, 0, 47, 3
67148.50, 76.579362, 290.213851, 340.1024, -0.0440007, 0.0006385, 7.08, 77, 0, 42, 3
67148.75, 76.579173, 290.214177, 341.0357, -0.0434314, 0.0007389, 7.67, 96, 0, 31, 3
67148.75, 76.579138, 290.215367, 341.2231, -0.0436628, 0.0004548, 8.00, 62, 0, 0, 0
67149.00, 76.578997, 290.214251, 341.8664, -0.0417305, 0.0012189, 8.26, 119, 0, 27, 3
67149.00, 76.578968, 290.215284, 342.0384, -0.0415898, 0.0023583, 8.46, 91, 0, 0, 0
67149.25, 76.578896, 290.211016, 342.0388, -0.0355122, 0.0062089, 10.48, 51, 0, 108, 2
67149.25, 76.578825, 290.214152, 342.6336, -0.0390594, 0.0025412, 8.48, 150, 0, 27, 3
67149.25, 76.578802, 290.215191, 342.8027, -0.0396572, 0.0039104, 7.99, 119, 0, 0, 0
67149.50, 76.578739, 290.210209, 342.4479, -0.0304889, 0.0097206, 10.83, 70, 0, 128, 2
67149.50, 76.578648, 290.214324, 343.3802, -0.0359311, 0.0039218, 9.53, 186, 0, 21, 3
```

Figure 1. Sample Data Record

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. The elevation measurement files and the summary files also may be opened by any text editor or word processing program that reads CSV files.

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 the 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 for 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 smoothes the data and reduces the data volume. Users desiring unsampled data should use the *IceBridge ATM L1B 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% 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 two slopes estimated are used to estimate surface elevations at points other than the center point through the use of the following algorithm shown in the equation below and described in Table 3:

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

Table 3. Surface Elevations Estimate Algorithm Variables

Variables	Description
ht	Height in meters at coordinates (phi, lambda)
phi	Latitude at location of interest (radians)
lambda	Longitude at location of interest (radians)
phi0	Latitude at center of tile (radians)
6378137	WGS84 ellipsoid semi-major axis (meters)
lambda0	Longitude at center of tile (radians)
SNslope	South/north slope of the tile
WEslope	West/east slope of the tile

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

Beginning with the 2013 Arctic campaign, all new data are provided in Version 2 CSV format. Data from 2012 and earlier campaigns remained in the previously-used Fixed-width, space-delimited ASCII format. On 10 August 2015, Version 1 fixed-width space-delimited ASCII text files for 31 March 2009 to 08 November 2012 were replaced with CSV files and were included with Version 2 data.

A header was added to the Version 2 data format. In Version 1, the data set consisted of file pairs for each data segment: one data file, `ILATM2_YYYYMMDD_HHMMSS_50pt_smooth_nadir3seg`, and one summary file, `ILATM2_YYYYMMDD_HHMMSS_50pt_icessn_summary`. The new header of the Version 2 data file contains information that had appeared in the summary file, making the summary file redundant.

3.2.3 Errors and Limitations

Uncertainty in slope estimates:
The uncertainty of the WGS84_Ellipsoid_Height, South-to-North_Slope, and West-to-East_Slope can be attributed to both physical topographical features and measurement error. The uncertainty in the WGS84_Ellipsoid_Height can be reasonably approximated with the RMS_Fit value. The uncertainty in the South-to-North_Slope and West-to-East_Slope can both be reasonably approximated with the equation:

Slope Sigma (m/m) = RMS_Fit / sqrt(500 * Number_Of_ATM_Measurements_Used)

Table 4. Uncertainty in South-to-North_Slope and West-to-East_Slope

Variables	Description
RMS_Fit	RMS fit of the ATM data to the plane in meters
Number_Of_ATM_Measurements_Used	Number of points used in estimating the plane parameters

Note: The RMS_Fit value is in centimeters and must be converted to meters to be used in the equation above.

Attenuated ATM signal 12 and 13 April 2010:

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.

Skipped glaciers and supplemented data for April 28, 2012:

The flight on 28 April 2012 traversed the notoriously turbulent regions over 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 Level-1B T4 data were supplemented by the these Level-1B 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 ATM L1B Qfit Elevation and Return Strength* data in the folder for 28 April 2012. 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.

ATM wide scan instrument failure 14 April 2015 - ATM Narrow Scan instrument fills data gap:

On 14 April 2015, the ATM wide-scan instrument suffered a failure in the scanning mechanism and did not collect data for that mission. However, the ATM narrow-scan instrument was operating normally and has been used to fill in the gap in ILATM2 data for this mission.

The ILATM2 averaged product is derived from the ILATM1B wide-scan elevation point cloud, when possible. The ILATM2 data splits the swath into three segments relative to the direction of flight: port-side, center, and starboard-side. From these strips, the data is further separated into 0.5-second-long tiles. With a nominal Above Ground Level (AGL) of 450 m, a swath width of 240 m, and a groundspeed of 100 m/s; this creates tiles that are 80 m wide and 50 m long. There is also a fourth tile created, called the nadir file, which is positioned directly below the aircraft. This tile is also nominally 80 m wide and 50 m long.

The ATM narrow-scan swath width is only about 40 m wide, so generating tiles equally-sized to the ATM wide-swath is not possible. For best results, it was decided to separate the lidar swath in half: port-side and starboard-side. For consistency, the along-track distance of the tiles is still 0.5 seconds. Therefore, for this delivery, the 14 April 2015 tiles are roughly 20 m wide and 50 m long. The nadir tile is also included, which is still nominally 80 m wide and 50 m long like the wide-swath ATM, and for straight-and-level flight includes the entire swath.

Fall 2015 Campaign:

For the Fall 2015 ATM data, some ATM elevations are adjusted slightly (~10 cm) to compensate for a systematic anomaly related to the ATM scanner azimuth. The overall mean elevation is not changed, but some elevations around the scan are adjusted upward or downward as a function of scanner azimuth. For further details on the adjustment method, see Yi et al. (2015).

Fall 2016 Campaign:

On 07 November 2016, the ATM wide-scan lidar (ATM6aT6) suffered a laser system failure and did not collect any usable ILATM1B data for that flight. Consequently, there are no ILATM2 data for this date.

Fall 2018 Campaign (updated May 2021)

The first release of the Operation IceBridge 2018 Antarctic ATM lidar data was delivered to NSIDC in Aug 2019 and contained 11 of the 24 campaign surveys (November 3, 2018 – November 16, 2018). Subsequently a problem was identified related to the application of the solid Earth tide correction in the data-processing stage. The resulting errors in elevations varied in both space and time over wavelengths of hundreds of kilometers. The error was corrected, the data reprocessed, and the resulting change in position was computed. Over the entire campaign, the vertical change (reprocessing minus initial processing) varied between -10.3 cm and +14.4 cm. The mean change for each survey flight varied between -6.0 cm and +5.1 cm, with a root sum of squares (RSS) deviation from the mean between 0.6 cm and 4.4 cm. The vertical change summary is presented in Figure 2. The mean is the large dot, the thick bar shows mean +/- the standard deviation, and the thin bar shows the full range from minimum to maximum. The horizontal change was less than 15cm throughout the campaign.

In addition, the T6 transceiver experienced a malfunction related to wear of the scanner mechanism. Errors were introduced into the knowledge of the scanner rotational position and thereby into the calculated horizontal and vertical location of the laser footprint. After October 19, 2018, the scanner was adjusted in the field and the scan speed reduced from 26 Hz to 20-21 Hz, thereby improving somewhat the instrument operation for October 20, 2018 and later. The errors comprised a systematic, reproducible component and a more random, variable component. The vertical part of the systematic component was estimated from suitable ground surfaces or crossings of two ATM tracks and removed to the extent possible. The variable component introduced perturbations at spatial scales varying from a portion of a full scan to across multiple scans. The mean elevation error averaged across roughly 1 s tends to zero because the impact varies both positive and negative in different parts of the scan.

The ATM T6 scanner mechanism was rebuilt after conclusion of the 2018 Antarctic campaign and operated well during the subsequent 2019 Arctic spring campaign. An improved method of measuring the scanner position was implemented for the 2019 Arctic summer campaign, further reducing geolocation errors related to the scanner mechanism.

The data set now includes all 24 surveys with the errors in solid earth tide corrected.

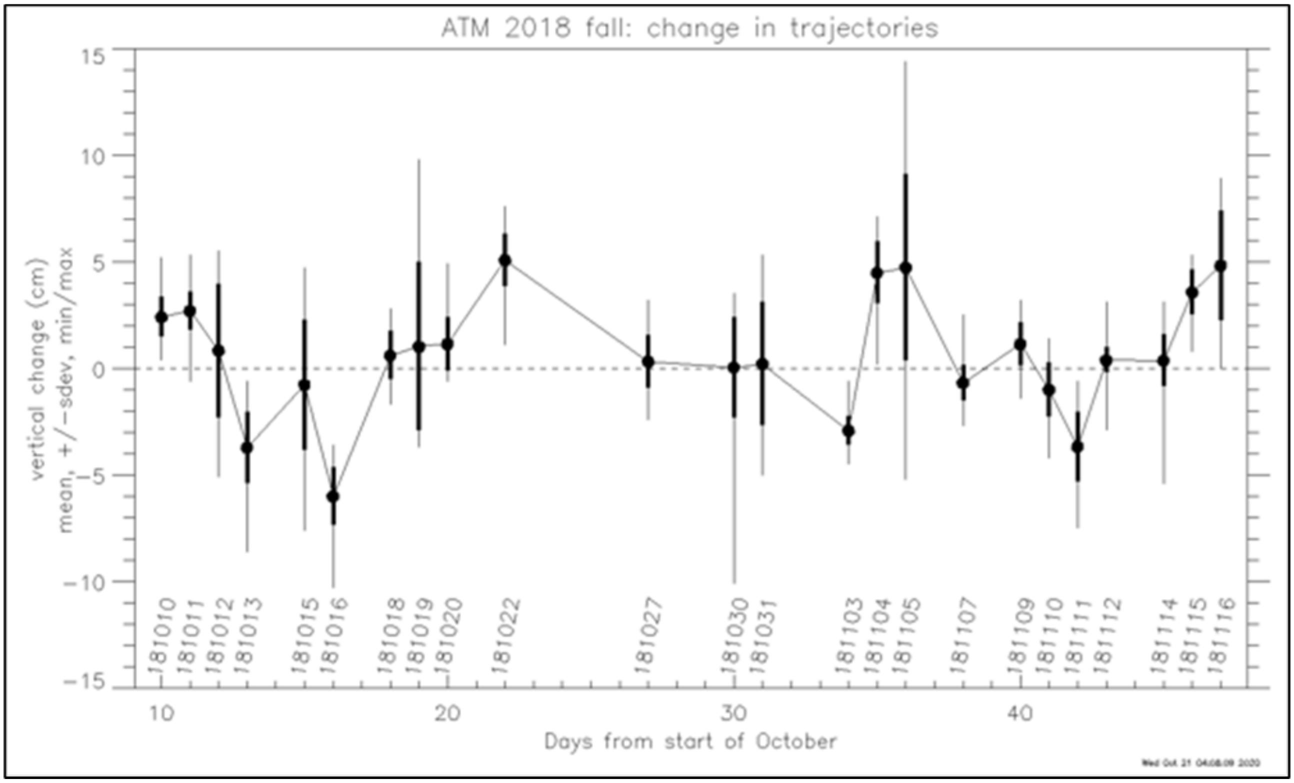

Figure 2. ATM 2018 Fall: Change in Trajectories After Error Corrections

Spring 2019 Campaign (updated May 2021)

The first release of the Operation IceBridge ATM lidar data was delivered to NSIDC in April 2020. At that time, a problem had been identified related to the application of the solid Earth tide correction in the data-processing stage. The resulting errors in elevations varied in both space and time over wavelengths of hundreds of kilometers. The error was subsequently corrected, the data reprocessed, and the resulting change in position was computed. Over the entire campaign, the vertical change (reprocessing minus initial processing) varied between -6.5 cm and +8.8 cm. The mean change for each survey flight varied between -1.8 cm and +2.8 cm, with a root sum of squares (RSS) deviation from the mean between 0.5 cm and 2.6 cm. The greatest magnitudes of vertical change tended to be at distances farthest from the staging airport (at Thule, April 3-23, 2019 or Kangerlussuaq, May 5-16, 2019). The results are presented in Figure 3. The horizontal change was less than 10 cm throughout the campaign.

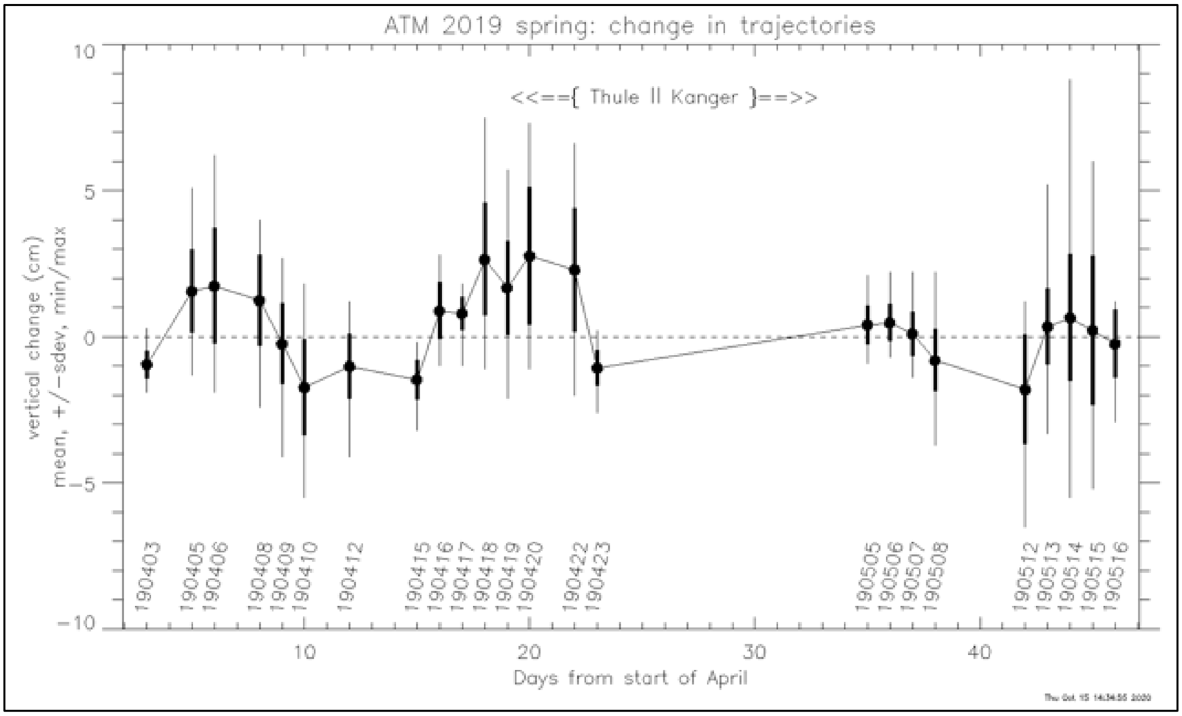

Figure 3. ATM 2019 Spring: Change in Trajectories After Solid Earth Tide Correction

> **Note:** The information below has been retained for provenance. The issues have been addressed as described in the preceding sections.

Fall 2018 and Spring 2019 Campaigns (10/10/2018 to 05/16/2019):

As compared to most other Operation IceBridge ATM laser altimetry data sets, this particular data set has certain limitations in accuracy that result from a recently identified problem related to the application of the solid Earth tide correction in the data processing stage. This error can cause long-wavelength errors in elevations that are less than decimeter in magnitude and which vary in both space and time. The error wavelength is typically hundreds of kilometers, so it should not significantly affect most analyses of this data set, but it can be smaller because it depends on the number and position of base stations used for the trajectory solution and on other factors including moon phase. The error only affects the 2018 DC-8 Antarctic and 2019 P-3 Arctic Spring ATM data sets published at NSIDC DAAC. Resolution of this error is in progress, and a future version of this data set will eliminate it. The user should consider the elevation issue in any scientific interpretation or other use of the data set. Users are requested to report their findings about data quality to NSIDC User Services, to be forwarded to the ATM team, for information and comment before publication or reporting elsewhere.

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 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

Brunt, K. M., Hawley, R. L., Lutz, E. R., Studinger, M., Sonntag, J. G., Hofton, M. A., … Neumann, T. A. (2017). Assessment of NASA airborne laser altimetry data using ground-based GPS data near Summit Station, Greenland. The Cryosphere, 11(2), 681–692. https://doi.org/10.5194/tc-11-681-2017

Kwok, R., Cunningham, G. F., Manizade, S. S., & Krabill, W. B. (2012). Arctic sea ice freeboard from IceBridge acquisitions in 2009: Estimates and comparisons with ICESat. Journal of Geophysical Research: Oceans, 117(C2), n/a-n/a. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2011JC007654

Yi, D., Harbeck, J. P., Manizade, S. S., Kurtz, N. T., Studinger, M., & Hofton, M. (2015). Arctic Sea Ice Freeboard Retrieval With Waveform Characteristics for NASA's Airborne Topographic Mapper (ATM) and Land, Vegetation, and Ice Sensor (LVIS). IEEE Transactions on Geoscience and Remote Sensing, 53(3), 1403–1410. https://doi.org/10.1109/tgrs.2014.2339737

4.1 Related Data Collections

- IceBridge ATM L1B Elevation and Return Strength
- IceBridge ATM L1B Elevation and Return Strength with Waveforms
- Pre-IceBridge ATM L1B Qfit Elevation and Return Strength
- Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
- 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

4.2 Related Websites

- ATM Trajectory Maps
- Airborne Topographic Mapper website at NASA Wallops Flight Facility
- Description of ATM QFIT Output Data (revised 13 February 2009)
- Description of DEM Generation, Dry Valleys, Antarctica
- IceBridge data website at NSIDC
- IceBridge website at NASA
- ICESat/GLAS website at NASA Wallops Flight Facility
- ITRF 2008 Specification website

5 CONTACTS AND ACKNOWLEDGMENTS

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5.1 Acknowledgments

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6 DOCUMENT INFORMATION

6.1 Publication Date

January 2017

6.2 Date Last Updated

August 2020