IceBridge ATM L4 Surface Elevation Rate of Change, Version 1

USER GUIDE

How to Cite These Data

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

Studinger, M. 2014, updated 2018. *IceBridge ATM L4 Surface Elevation Rate of Change, 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/BCW6CI3TXOCY. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IDHDT4

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

One application of laser altimetry data over ice sheets is to monitor the surface elevation change over time. The intent of this data product is to allow scientists to quickly view those surface elevation changes without having to download the entire collection of ATM data and perform the analysis individually. The ATM team has computed the ice surface elevation changes for all of the ATM-flown missions and made the results available for scientists to browse. Upon locating a region of interest, a scientist can download the data sets that contain the relevant data and perform a more detailed analysis. A set of maps in PNG format provides a graphic summary of the data set.

1.1 Format

The surface elevation rate of change data files are Comma Separated Value (CSV) ASCII text in which each record (row) corresponds to a location where two ATM swaths from different years contain coincident measurements. For each such overlap location, a surface elevation rate of change value has been calculated. The first line in the file contains a title for each column. Each CSV file is paired with an associated XML file, which contains additional metadata, and a PNG image, which shows the location of the data.

1.2 File and Directory Structure

Data files include information from multiple years. For example, the folder /`2014.04.01`/ contains the data file `IDHDT4_2015-2014_ATM_dhdt_canada.csv`, which includes `dH/dt` values from 2015 test data referenced to 2014 values.

1.3 File Naming Convention

The surface elevation rate of change data files use the following naming convention and as described in Table 1:

Example file names:

`IDHDT4_2013-1998_ATM_dhdt_greenland.csv`

`IDHDT4_2013-1998_ATM_dhdt_greenland.csv.xml`

`IDHDT4_2013-2012_ATM_dhdt_greenland.csv.png`

`IDHDT4_YYYY-yyyy_ATM_dhdt_REGION.xxx`

Table 1. File Naming Convention

Variable	Description
IDHDT4	File name prefix indicating elevation rate of change data
YYYY	Four-digit year of test campaign
yyyy	Four-digit year of reference campaign
ATM	Airborne Topographic Mapper instrument
dhdt	Surface Elevation Rate of Change
REGION	Region designation for campaign (e.g., Greenland, Antarctica, Canada, Alaska, Iceland, and Svalbard)
.xxx	Indicates CSV, XML, or PNG file.

Note:

Data file for 2016-2014 is comprised of three regional files, designated by latitude:

```
IDHDT4_2016-2014_ATM_dhdt_antarctica_75S.csv
IDHDT4_2016-2014_ATM_dhdt_antarctica_81S.csv
IDHDT4_2016-2014_ATM_dhdt_antarctica_88S.csv
```

1.4 File Size

The individual CSV surface elevation rate of change data files can range in size from approximately 2 KB to 68 MB, depending on the number of coincident elevation measurements. The total volume of PNG images is 12 MB. The total volume of the entire data set is approximately 2.5 GB.

1.5 Spatial Coverage

The spatial coverage for the surface elevation rate of change data set is bounded by:

Southernmost latitude: 90° S
Northernmost latitude: 90° N
Westernmost longitude: 180° W
Easternmost longitude: 180° E

1.5.1 Spatial Resolution

Each record of data in this data set corresponds to an area where two ATM lidar swaths have coincident measurements. This overlap can occur in one of two ways: when one swath intersects with another swath (crossing) or when one swath reoccupies the same flight path as another swath (along-track). The amount of overlap may vary due to the aircraft altitude above ground level (AGL), the angle of intersection in the case of crossing swaths, and the track separation in the case of along-track overlap. For the simplest case of two perpendicular crossing swaths at the nominal flight AGL of 450 m and 30° swath width, the area of overlap is a square with side equal to the width of the ATM swath; or a 240 m x 240 m square. For along-track comparisons, a difference is computed at regular intervals, typically 0.5 seconds of flight, which corresponds to 60-meter spacing at nominal 120 m/s flight velocity.

1.5.2 Projection and Grid Description

The surface elevation rate of change data are discrete points. Locations are given in geographic latitude and longitude defined in the WGS84 ellipsoid coordinate system.

1.6 Temporal Information

1.6.1 Temporal Coverage

23 June 1993 to 01 May 2018.

1.6.2 Temporal Resolution

The surface elevation rate of change measurements exist wherever there are coincident ILATM1B measurements. Therefore, the temporal resolution of this data set is seasonal, the same as for the ILATM1B data set, and includes every flight since 23 June 1993.

1.7 Parameter or Variable

1.7.1 Parameter Description

The main parameter provided in this data set is the average rate of change, dH/dt, of the surface elevation between two measurement times. Parameters contained in the data files are described in Table 2.

Table 2. ASCII Text File Column Description

Parameter	Description	Units
Latitude	Average latitude of the coincident points extracted from the test pass	Degrees
Longitude	Average longitude of the coincident points extracted from the test pass	Degrees
Ellipsoid Elevation	Average elevation of the coincident points extracted from the test pass, relative to WGS84 ellipsoid	Meters
dH/dt	Surface Elevation Rate of Change (newer – older)	Meters/year

Test Date	Date when test trajectory passed over coincident location	YYMMDD
Test Time	Seconds of day when test trajectory passed over coincident location	Seconds
Ref Date	Date when reference trajectory passed over coincident location	YYMMDD
Ref Time	Seconds of day when reference trajectory passed over coincident location	Seconds
Trajectory Separation	Separation between test and reference trajectories	Meters
Number of Pairs Used	Number of matching pairs of ILATM1B elevation measurements used in the calculation of the dH/dt	Count
RMS	Root mean square of the individual height differences after compensating for the estimated dH/dt	Meters

1.7.2 Sample Data Record

Figure 1 shows a sample of the `IDHDT4_2013-1998_ATM_dhdt_greenland.csv` data file.

```
# Latitude(deg), Longitude(deg), Ellipsoid_Elevation(m), dH/dt(m/yr), Test_Date(YYYYMMDD), Test_Time
(UTC_Sec_Of_Day), Ref_Date(YYYYMMDD), Ref_Time(UTC_Sec_Of_Day), Trajectory_Separation(m),
Number_Of_Pairs_Used, RMS_Error(m)
66.952250, 309.025500, 31.362, 0.102, 20130402, 63495.50, 19980627, 71281.77, 167.9, 3014, 0.08
66.952200, 309.026070, 31.457, 0.104, 20130402, 63496.00, 19980627, 71281.41, 150.7, 8920, 0.08
66.952220, 309.026120, 31.458, 0.104, 20130402, 63496.50, 19980627, 71281.05, 134.1, 8796, 0.08
66.952580, 309.027800, 31.519, 0.104, 20130402, 63497.00, 19980627, 71280.68, 118.2, 9813, 0.08
66.952580, 309.027800, 31.519, 0.104, 20130402, 63497.50, 19980627, 71280.31, 103.0, 9813, 0.08
66.953060, 309.029820, 31.585, 0.104, 20130402, 63498.00, 19980627, 71279.94, 88.4, 11594, 0.08
```

Figure 1. Sample data record.

The corresponding `IDHDT4_2013-1998_ATM_dhdt_greenland.csv.png` image is shown in Figure 2.

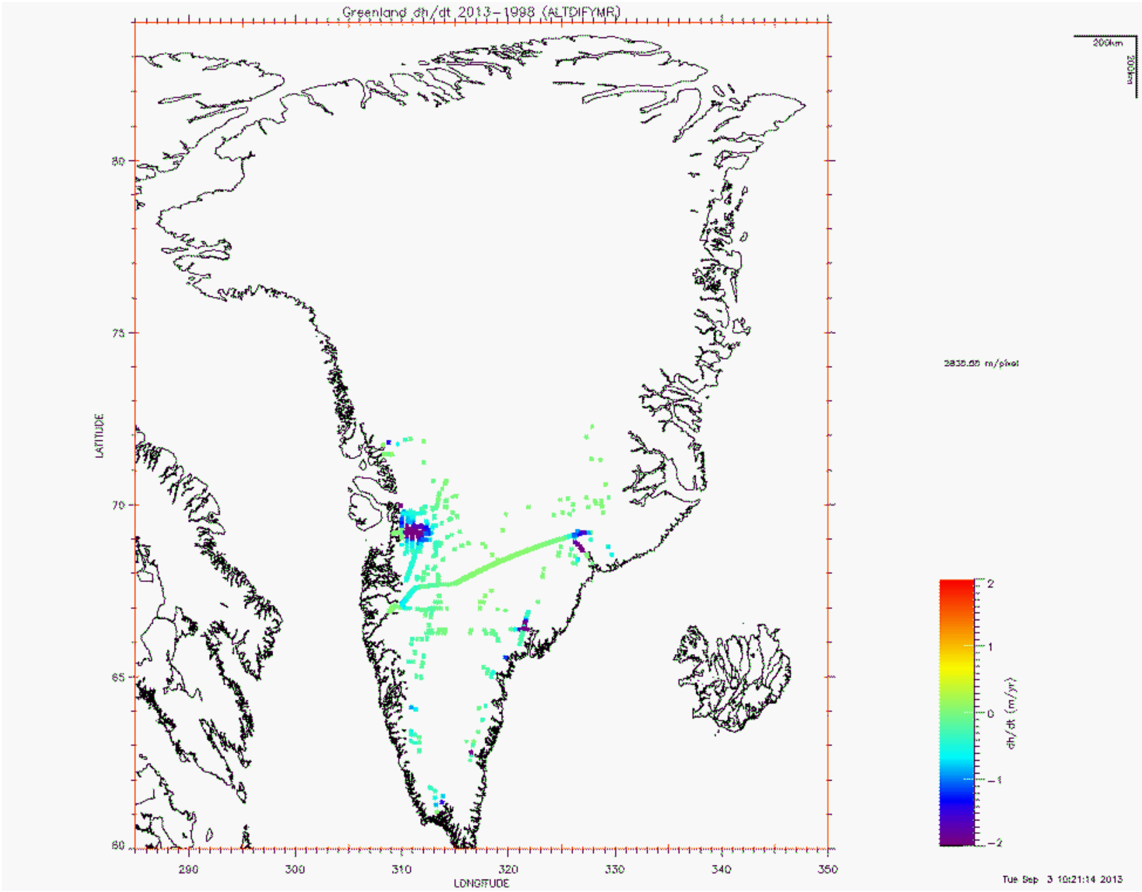

Figure 2. Sample PNG image.

2 SOFTWARE AND TOOLS

2.1 Software and Tools

The CSV data files may be opened using any software capable of reading ASCII text data.

The PNG files may be viewed using any graphic software capable of reading Portable Network Graphics files.

XML files may be viewed in browser windows, or any XML reading software.

2.2 Quality Assessment

An extensive quality assessment is performed on ILATM1B data, which provide the input to the change computation. Graphical presentations of the elevation change rate are created as color-coded geographic maps and as scatter plots (typically, surface elevation rate of change versus elevation). Visual inspection of these figures provides a qualitative assessment of consistency across sampling dates and other data sources, and correlation with geographic features. The RMS and Number of Pairs Used data fields also can inform regarding the quality of individual records. RMS is primarily dependent on surface roughness, although a high RMS or a limited number of points reduces the accuracy of the computed elevation change rate.

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

For details on measurements, see the documentation for the IceBridge ATM L1B Qfit Elevation and Return Strength (ILATM1B) data set.

3.2 Data Acquisition Methods

Surface Elevation Rate of Change is a derived product. Computation uses the point measurements in the IceBridge ATM L1B Qfit Elevation and Return Strength (ILATM1B) data set.

3.3 Derivation Techniques and Algorithms

The surface elevation rate of change measurements are computed for each coincident location, found by comparing one year's flight trajectories against those of a different year. By comparing the flight trajectories for a combination of any two years, a single file is created that contains the data for all of the coincident locations.

For each location where there exist Airborne Topographic Mapper (ATM) widescan ILATM1B elevation measurements from two different campaigns, a surface elevation difference is computed and divided by the difference in times when the data were collected. This computation yields a rate of change of the surface elevation, which is presented in meters per year, with negative values indicating a decrease in the surface elevation over time.

The Surface Elevation Rate of Change is computed by comparing a test ILATM1B data set against a reference ILATM1B data set. A list of reference trajectories and the test trajectories are defined in a command file. For each pair of reference/test trajectories, the software determines the locations, if any, where the two trajectories overlap. Overlap is reached when the horizontal distance between a position in one trajectory and a position in the other trajectory is less than 200 meters. The trajectory timestamp for each overlap location is then used to find corresponding ILATM1B data for each pass. For each reference ILATM1B laser footprint, all the test ILATM1B footprints are found within a specified radius (typically ~2.5 meters). If enough ILATM1B test/reference pairs (typically more than 500) are found, then an elevation difference is calculated for each. Elevation differences greater than 300 meters are removed. The remaining elevation differences are averaged and divided by the elapsed date-time interval to yield a single surface elevation rate of change measurement for each overlap location. The RMS of these elevation differences is included in the output data record, where the RMS is the square root of the average squared deviation between the individual elevation differences and the overall mean. The rate of change is always presented in terms of the newer measurement minus the older measurement, regardless of which set is the test or reference.

Note: The "typical" numeric values in the description above have been experimentally determined to provide a reasonable compromise between accuracy of comparison points and number of comparison points, but are adjustable parameters that can be set in the command file. Height differences are computed by the numerical subtraction of the elevation found in two different years of ILATM1B data. The elevation for any given year is defined within a particular geodetic reference frame, which may differ between the two years being considered. Precise computation of surface elevation change using this data set must therefore incorporate an additional adjustment for changes in reference frames. This adjustment will be larger for earlier 1990s measurements than later 2010s. More information regarding reference frames can be found on the the International Terrestrial Reference Frame (ITRF) website. Note also that precise computation of change in ice volume should consider vertical crustal motion.

3.3.1 Data Collection Platforms Since 1993

Table 3. Data Collection Platforms Since 1993

Campaign	Platform Short name	Aircraft ID	Platform Long Name
1993 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1994 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1995 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1996 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1997 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1998 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
1999 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2000 Arctic	Kenn Borek DHC-6	C-FSJB	de Havilland DHC-6 Twin Otter
2001 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2001 Antarctica	Kenn Borek DHC-6	C-FSJB	de Havilland DHC-6 Twin Otter
2002 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2002 Antarctica	Chilean Armada P-3	CA-408	Lockheed P-3A Orion

Campaign	Platform Short name	Aircraft ID	Platform Long Name
2003 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2003 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2004 Antarctica	Chilean Armada P-3	CA-408	Lockheed P-3A Orion
2005 Arctic	Kenn Borek DHC-6	C-FSJB	de Havilland DHC-6 Twin Otter
2005 Arctic	Twin Otter International DHC-6	N572AR	de Havilland DHC-6 Twin Otter
2006 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2006 Arctic	Kenn Borek DHC-6	C-FSJB	de Havilland DHC-6 Twin Otter
2007 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2007 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2008 Arctic	Kenn Borek DHC-6	C-GCKB	de Havilland DHC-6 Twin Otter
2008 Antarctica	Chilean Armada P-3	CA-408	Lockheed P-3A Orion
2009 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2009 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2010 Arctic	NASA DC-8	N817NA	Douglas DC-8
2010 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2010 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2011 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2011 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2012 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2012 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2013 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2013 Antarctica	NASA P-3B	N426NA	Lockheed P-3B Orion
2014 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion
2014 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2015 Arctic	NASA C-130	N439NA	Lockheed C-130 Hercules
2015 Antarctica	NASA DC-8	N817NA	Douglas DC-8
2016 Arctic	NOAA WP-3D	N42RF	Lockheed WP-3D Orion
2017 Arctic	NASA P-3B	N426NA	Lockheed P-3B Orion

3.3.2 Trajectory and Attitude Data

Trajectory and attitude data are incorporated in the ILATM1B data set from which the elevation change rate is computed.

3.3.3 Processing Steps

The data provider performs the following processing steps.

1. Generate a list of GPS trajectory files for every flight in a campaign
2. Set up the command file with the trajectory list and the location of the ILATM1B data files for each campaign
3. Run the processing software to compute the surface elevation rate of change measurements

3.3.4 Errors and Limitations

For details on error sources, see the documentation for the IceBridge ATM L1B Qfit Elevation and Return Strength (ILATM1B) data set.

3.4 Sensor or Instrument Description

For details on the ATM sensor, see the documentation for the IceBridge ATM L1B Qfit Elevation and Return Strength (ILATM1B) data set.

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:10.1029/2011JC007654.

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
- IceBridge Narrow Swath ATM L1B Qfit Elevation and Return Strength
- IceBridge ATM L2 Icessn Elevation, Slope, and Roughness
- Trajectory Maps - ATM
- 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 website at NASA Wallops Flight Facility
- Description of ATM QFIT Output Data (revised 13 February 2009)
- 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

5.1 Contacts

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5.2 Acknowledgments

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6 DOCUMENT INFORMATION

6.1 Publication Date

18 April 2014

6.2 Date Last Updated

01 August 2018