IceBridge Merged Photon Counting Lidar/Profiler L4 Surface Slope and Elevations, Version 1

USER GUIDE

How to Cite These Data

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

Blankenship, D. D., S. D. Kempf, D. A. Young, and L. E. Lindzey. 2014. *IceBridge Merged Photon Counting Lidar/Profiler L4 Surface Slope and Elevations, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/STLZLZ7ZI7Z4. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ILSNP4

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set consists of airborne photon counting lidar and laser altimetry observations. The following are the goals of this product:

- to provide an estimate of surface elevation along the aircraft ground track
- to provide estimates of local surface slopes
- to parameterize the quality of the Photon Counting Lidar data set.

Data files contain attributes for Elevation and Slope, and Photon Altimetry. Top level properties and attributes include file level metadata as well as campaign details.

1.1 Format

The data files are Hierarchical Data Format (HDF5). Each data file is paired with an associated XML file. The XML files contain location, platform, and instrument metadata.

1.2 File Naming Convention

The HDF5 files are named according to the following convention and as described in Table 1:

File name examples:

`ILSNP4_2012339_ICP5_JKB2h_F16T04a_000.h5`

`ILSNP4_2012339_ICP5_JKB2h_F16T04a_000.h5.xml`

`ILSNP4_YYYYDOY_PPP_JKB2S_TTTT_nnn.xxx`

Table 1. HDF5 File Naming Convention

Variable	Description
ILSNP4	Short name for IceBridge Merged Photon Counting Lidar/Profiler L4 Surface Slope and Elevations
YYYY	Four-digit year of survey
DOY	Day of year of survey
PPP	Geographic area (Project)
JKB2S	Host platform for timing (System)

TTTT	Transect name within Project
nnn	Granule within line
.xxx	Indicates HDF5 file (.h5), or XML file (.xml)

1.3 Spatial Information

1.3.1 Coverage

The target region for this data is East Antarctica and the Antarctic Peninsula. Please see the metadata in the top level of each HDF5 data file for targets for each granule.

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

1.3.2 Spatial Resolution

10 meter spot on the ground at 800 meters.

1.3.3 Projection and Grid Description

Polar Stereographic true at −71 degrees latitude EPSG:3031

1.4 Temporal Coverage

These data were collected from 25 November 2010 to 04 December 2012 as part of the ICECAP, ICEGRAV, NSF, NERC, and Operation IceBridge funded campaigns.

1.4.1 Temporal Resolution

ICECAP campaigns were conducted on an annual basis. East Antarctic campaigns for this data set typically extend from November to early January.

1.5 Parameter or Variable

1.5.1 Parameter Description

Parameters are organized in the HDF5 files as Elevation and Slope attributes, and Photon Altimetry attributes. File level HDF5 attributes store metadata describing targets, collection parameters and details of funding and logistical support.

Elevation and Slope attributes are described in Table 2.

Table 2. Elevation and Slope Attributes Description

Parameter	Description	Units
DOY	Day Of Year of survey	Day
DScontinuous_time_of_day	Seconds since 2012-12-04 0:0:0	Seconds
DSdelta_time_start	Seconds since 2012-12-04T00:12:03	Seconds
YEAR	Year of survey	Year
latitude	Latitude of laser altimeter spot (WGS-84/ITRF08)	Degrees North
longitude	Longitude of laser altimeter spot (WGS-84/ITRF08)	Degrees East
mean_swath_surface_elevation	Mean nadir surface elevation of plane through all beams of the photon counting lidar swath (WGS-84/ITRF08)	Meters
point_surface_elevation	Surface elevation of laser altimeter spot (WGS-84/ITRF08)	Meters
point_swath_divergence_angle	Angular difference between normals of the swath best fit plane and the along track laser altimeter	Degrees
seconds_of_day	Seconds of day of survey	Seconds (UTC)
x_gradient	Gradient in x direction with respect to polar stereographic −71 projection (EPSG:3031)	dimensionless
y_gradient	Gradient in y direction with respect to polar stereographic −71 projection (EPSG:3031)	dimensionless

Photon Altimetry includes information for BEAM0 through BEAM5. The exact location of the beams varies with scan pattern, but beam 0 and 1 are located along track, beam 2 and 3 are located at the edge of the scan pattern, and beams 4 and 5 are halfway between the edge and the flight track. Beam 0 was not used on data collected with a linear scan pattern. Please see granule metadata for specific details of beam layout and scan pattern used.

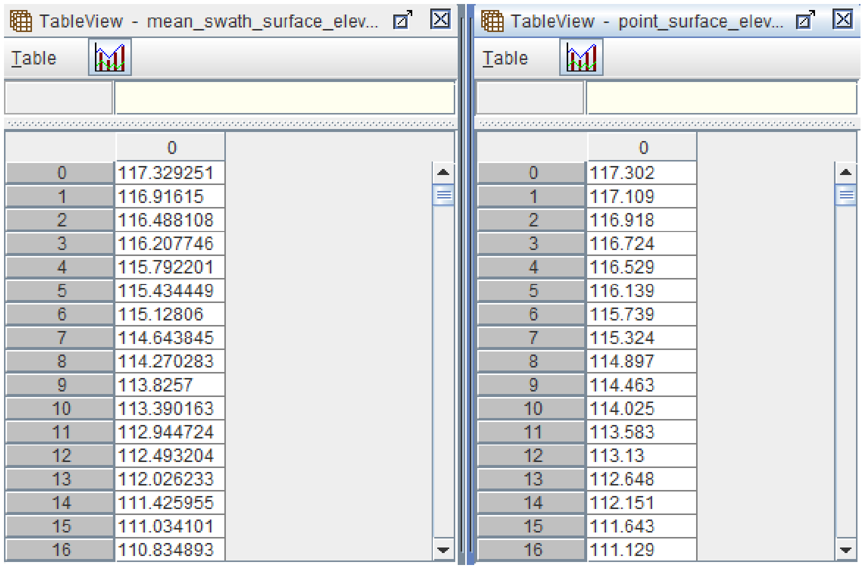
Photon Altimetry beam attributes are described in Table 3.

Table 3. Photon Altimetry Beam Attributes Description

Parameter	Description	Units
DOY	Day Of Year of survey	Day
DScontinuous_time_of_day	Time since midnight of the first day of acquisition.	Seconds
DSdelta_time_start	Time since the start of the transect	Seconds
X_range_vector	Cross track component of detected surface spot with respect to the lidar body; positive is along right wing	Meters
YEAR	Year of survey	Year
Y_range_vector	Along track component of detected surface spot with respect to the lidar body; positive is toward nose	Meters
Z_range_vector	Along track component of detected surface spot with respect to the lidar body; positive is down	Meters
course_noise_rate	Number of photons in current beam in a 5 meter window 20 meters above surface over 0.25 second interval	Counts
latitude	Latitude of detected surface spot (WGS-84/ITRF08)	Degrees North
leading_quartile_range	Range between detected surface and the 25th percentile photon above the surface, from a total population from a 15 meter window around the surface	Meters
longitude	Longitude of detected surface spot (WGS-84/ITRF08)	Degrees East
peak_event_count_course	Number of photons in current beam in a 5 meter window around the surface counted over 0.25 second period	Counts
peak_event_count_fine	Number of photons in current beam in a 1 centimeter window around the surface counted over 0.25 second period	Counts
point_surface_elevation	Surface elevation of detected surface spot (WGS-84/ITRF08)	Meters
seconds_of_day	Seconds of day of survey	Seconds UTC

1.5.2 Sample Data Record

Below are `mean_swath_surface_elevation`, and `point_surface_elevation` values from a sample of the `ILSNP4_2012339_SCT_JKB2h_Y46b_000.h5` data file as displayed in the HDFView tool.



TableView - mean_swath_surface_elev...

	0
0	117.329251
1	116.91615
2	116.488108
3	116.207746
4	115.792201
5	115.434449
6	115.12806
7	114.643845
8	114.270283
9	113.8257
10	113.390163
11	112.944724
12	112.493204
13	112.026233
14	111.425955
15	111.034101
16	110.834893

TableView - point_surface_elev...

	0
0	117.302
1	117.109
2	116.918
3	116.724
4	116.529
5	116.139
6	115.739
7	115.324
8	114.897
9	114.463
10	114.025
11	113.583
12	113.13
13	112.648
14	112.151
15	111.643
16	111.129

Figure 1. Sample from the ILSNP4_2012339_SCT_JKB2h_Y46b_000.h5 data file of mean_swath_surface_elevation, and point_surface_elevation values

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

Data were acquired from an aircraft flown between 500 and 1500 meters above the ice sheet surface. A laser altimeter and a scanning photon counting lidar system collected range data, while IMU and GPS instruments were used to collect trajectory information.

2.2 Derivation Techniques and Algorithms

Input products are:

- IceBridge GPS/IMU L1B Primary Position and Attitude Solution (IPUTG1B) trajectory data set
- IceBridge Sigma Space Photon Counting Lidar L1B Time-Tagged Nadir Photon Ranges (ILSNP1B) subset of the photon counting lidar data ranges
- IceBridge Riegl Laser Altimeter L2 Geolocated Surface Elevation Triplets (ILUTP2) geolocated surface elevation data from the Riegl laser profiler.

Please review descriptions of these data products for geolocation, initial filtering, and calibration methods.

In order to determine the surface location, the ranges are extracted from the beam's subset photon cloud. For each beam, a coarse histogram is built along the Z_range_vector of the lidar coordinate system with 5 meter bin resolution. The peak bin is selected as the coarse z distance.

In order to determine a more precise location, we return the median z distance of the photons in the maximum coarse bin and the two adjacent bins.

Using the known angles for this beam and the computed distance to the surface in the z direction, we calculate x distance and y distance in the lidar reference frame. We then rotate and translate the lidar range vector using the reported aircraft orientation using the estimated pointing biases and measured lever arm between the IPUTG1B coordinate system and the lidar.

This vector is then added to the aircraft trajectory to obtain the surface location in the WGS-84 reference frame. Statistics on the shape of the surface return peak and background noise character were also reported.

2.2.1 Trajectory and Attitude Data

Please see each granule's HDF5 attributes, and the IPUTG1B dataset for details of trajectory collection.

2.2.2 Processing Steps

As absolute ranges for the lidar may have a bias due to uncertainties in the high resolution timing oscillator, the lidar data are integrated with simultaneously acquired laser profiler data.

The local surface slope was determined by fitting a plane to a 400 meter wide segment of the lidar surface elevation data, which was integrated with the laser altimetry ILSNP1B product, and provided the final surface elevation.

2.2.3 Error Sources

The lidar coarse clock used to calculate ranges has a temperature and acquisition card dependent uncertainty of 0.1 percent, which translates to a scaling error in range of ~80 cm. For this reason, we use the ILUTP2 data to calibrate results in the Elevation and Slope part of the ILSNP4 dataset.

GPS relative errors are estimated by Waypoint to be typically 6 cm where a convergent combined GPS-IMU solution is produced, with orientation errors of 50 μrad.

For 2010-2011 data, GPS errors were higher (typically 10 cm) as the GPS data was not constrained by IMU data.

A simple, static 1-D atmospheric model is used to estimate delays due to propagation through air.

2.2.4 Instrument Description

Instrumentation is comprised of the following components

Sigma Space Mapping Photon Counting Lidar system

- Lidar scan pattern: circular
- Lidar scan rate: 18 hertz
- Lidar shot rate: 20 kilohertz
- Lidar wavelength: 532 nanometers

As described on the University of Texas Institute for Geophysics Web site, the scanning photon counting lidar images the surface below the aircraft with one hundred laser beamlets which are mechanically scanned in a swath either side of the flight path. A one hundred channel photon counting receiver captures return photons and records time of flight and time tag data allowing a three dimensional reconstruction of the surface flown over. The system can make 2.2 million measurements per second. At the typical survey elevation of 800 meters above the ice sheet, the swath width is about 400 meters.

Reigl LD90-3800HiP-LR Distance Meter

Novatel SPAN OEM-4 GPS; iMAR FSAS IMU

3 SOFTWARE AND TOOLS

The following external links provide access to software for reading and viewing HDF5 data files. Please be sure to review instructions on installing and running the programs. Version 1.8.5 of the HDF5 libraries was used.

HDFView: Visual tool for browsing and editing HDF4 and HDF5 files.

h5py: Free python module for interacting with HDF5 data. Depends on the SciPy/NumPy suite of Python Modules.

Matlab: The h5read command in recent versions of Mathworks Matlab can also access HDF5 variables.

For additional tools, see the HDF-EOS Tools and Information Center.

4 VERSION HISTORY

On 25 April, 2014, the the ILSNP4 HDF5 data replaced the ASCII data in the previous ILSNP2 data set. The data are newly processed as a Level-4 product. ILSNP4 includes a composite profiler-lidar product for altimetry and cross track slope. Vector rotations now occur in Earth Centered Earth Fixed space.

5 RELATED DATA SETS

- IceBridge Sigma Space Prototype L0 Raw Time-of-Flight Data
- IceBridge Sigma Space Lidar L0 Raw Time-of-Flight Data
- IceBridge Sigma Space Photon Counting Lidar L1B Time-Tagged Nadir Photon Ranges
- IceBridge GPS/IMU L1B Primary Position and Attitude Solution

6 RELATED WEB SITES

- IceBridge Product Web Site
- IceBridge Web site at NASA
- ICESat/GLAS Web site at NASA Wallops Flight Facility
- ICESat/GLAS Web site at NSIDC
- University of Texas Institute for Geophysics Web site

7 CONTACTS AND ACKNOWLEDGMENTS

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8 DOCUMENT INFORMATION

8.1 Document Creation Date

April 2014

8.2 Document Update Date

August 2015