IceBridge LVIS L1B Geolocated Return Energy Waveforms, Version 1

USER GUIDE

How to Cite These Data

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

Blair, J. B. and M. Hofton. 2011, updated 2014. *IceBridge LVIS L1B Geolocated Return Energy Waveforms, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/E50N2D14492H [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ILVIS1B

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set contains laser altimetry return energy waveform measurements taken from NASA's Land, Vegetation, and Ice Sensor (LVIS) over areas including Greenland and Antarctica. The data were collected as part of Operation IceBridge funded campaigns.

1.1 File Information

1.1.1 Format

The LVIS Level-1B Geolocated Return Energy Waveforms data files are in big-endian binary format.

1.1.2 File and Directory Structure

Data files are available via HTTPS in folders organized by date, for example /2012.05.10/. Each data file is paired with an associated XML file. The XML files contain location, platform, and instrument metadata.

1.1.3 File Naming Convention

LVIS Level-1B Geolocated Return Energy Waveforms binary files are named according to the following convention and as described in Table 1.

```
ILVIS1B_LOYYYY_MMDD_RYYMM_nnnnnn.xxx
```

File name example:

```
ILVIS1B_GL2012_0505_R1210_063682.LGW4
ILVIS1B_GL2012_0505_R1210_063682.LGW4.xml
```

Table 1. Binary File Naming Convention

Variable	Description
ILVIS1B	Short name for IceBridge LVIS L1B Geolocated Return Energy Waveforms data
LOYYYY	Campaign identifier. LO = location, where GL = Greenland and AQ = Antarctica. YYYY= four-digit year of campaign.
MMDD	Two digit month, two-digit day of campaign
RYYMM	Date (YY year/ MM month) of the data release
nnnnnn	Number of seconds since UTC midnight of the day the data collection started
xxx	Indicates file type: binary (.LGW4) or XML (.xml)

1.1.4 File Size

Binary data files range from approximately 17 MB to 913 MB.

XML files range from approximately 9 KB to 88 KB.

1.1.5 Volume

Data volume for the full data set is approximately 834 GB.

1.2 Spatial Coverage

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

1.2.1 Spatial Resolution

The spatial resolution is nominally 20 meters but varies with aircraft altitude. Laser spot size is a function of beam divergence and altitude. Nominal spot spacing is a function of scan rate and pulse repetition rate.

1.2.2 Projection and Grid Description

International Terrestrial Reference Frame (ITRF 2000), WGS-84 Ellipsoid.

1.3 Temporal Coverage

ILVIS1B Version 1 data were collected periodically from 14 April 2009 to 10 May 2012 as part of Operation IceBridge funded campaigns.

1.3.1 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.

1.4 Parameter or Variable

The Version 1 LVIS Level-1B files include geolocated return energy waveforms. The LVIS Level-1B LGW4 files are described in Table 2.

1.4.1 Parameter Description

Table 2. LGW4 File Parameter Description

Parameter	Bytes	Type	Description	Units
LVIS_LFID	4	Unsigned long integer	LVIS file identification, including date and time of collection and file number. The third through seventh values in first field represent the Modified Julian Date of data collection.	n/a
SHOTNUMBER	4	Unsigned long integer	Laser shot assigned during collection	n/a
AZIMUTH	4	Float	Azimuth angle of laser beam	Degrees
INCIDENTANGLE	4	Float	Off-nadir angle of laser beam	Degrees
RANGE	4	Float	Along-laser-beam distance from the instrument to the ground	Meters
TIME	8	Double	UTC decimal seconds of the day	Seconds
LON_0	8	Double	Longitude of the highest sample in the waveform	Degrees east
LAT_0	8	Double	Latitude of the highest sample in the waveform	Degrees north
Z_0	4	Float	Elevation of the highest sample in the waveform	Meters
LON_527	8	Double	Longitude of the lowest sample in the waveform	Degrees east
LAT_527	8	Double	Latitude of the lowest sample in the waveform	Degrees north
Z_527	4	Float	Elevation of the lowest sample in the waveform	Meters
SIGMEAN	4	Float	Signal mean noise level	Counts

Parameter	Bytes	Type	Description	Units
TXWAVE	2 x 120	Unsigned integer array	Transmitted waveform (120 samples, 2 bytes per sample)	Counts
RXWAVE	2 x 528	Unsigned integer array	Received waveform (528 samples, 2 bytes per sample)	Counts

LGW4 binary data contain 1368 bytes per record.

1.4.2 Sample Data Record

Below are sample output records generated from 25 October 2009 data using the LVIS C reader. The reader creates two output records for every one input record. The first output record contains all data parameters except the received waveform, and the second output record contains the received waveform.

```
1655129009       6544418   359.6823   4.5714   8822.044967635.331149     286.5491838992     -85.9947894606     1657.5552
          286.5491749134     -85.9946762533     1500.0715 15.5205  0018     0017     0018     0016     0017     0016
          0018     0017     0018     0016     0018     0016     0017     0016     0018     0016     0018     0016
          0018     0016     0018     0016     0018     0016     0017     0016     0018     0016     0018     0016
          0017     0016     0018     0016     0018     0016     0018     0016     0019     0018     0025     0048
          0098     0117     0088     0053     0042     0032     0030     0024     0023     0022     0022     0020
          0020     0019     0021     0018     0018     0018     0018     0017     0018     0016     0019     0017
          0018     0018     0016     0018     0019     0016     0019     0016     0018     0016     0018     0016
          0019     0017     0000     0000     0000     0000     0000     0000     0000     0000     0000     0000
          0000     0000     0000     0000     0000     0000     0000     0000     0000     0000     0000     0000
          0000     0000     0000     0000     0000     0000     0000     0000     0000     0000     0000     0000
          0000     0000     0000     0000     0000     0000
```

Figure 1. Sample data parameter without waveform output record generated from 25 October 2009 data.

0016	0014	0018	0015	0016	0016	0015	0016	0017	0013	0016	0015	0015
	0016	0016	0015	0018	0015	0015	0016	0016	0014	0018	0014	0016
	0016	0015	0016	0016	0014	0017	0015	0015	0016	0016	0015	0018
	0015	0015	0016	0016	0015	0017	0014	0016	0016	0016	0015	0017
	0014	0017	0014	0015	0016	0016	0014	0017	0015	0015	0016	0016
	0014	0017	0014	0016	0016	0016	0015	0017	0014	0016	0016	0015
	0016	0016	0014	0016	0015	0015	0016	0017	0014	0017	0015	0016
	0016	0016	0014	0018	0014	0016	0015	0015	0016	0017	0015	0018
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	0015	0018	0015	0016	0016	0016	0015	0016	0016	0016	0015	0018
	0015	0016	0015	0016	0015	0016	0016	0017	0014	0017	0016	0015
	0016	0016	0015	0018	0015	0016	0015	0016	0015	0017	0015	0016
	0016	0016	0015	0016	0015	0017	0015	0017	0016	0016	0014	0018
	0014	0016	0016	0016	0015	0017	0015	0017	0016	0017	0015	0019
	0015	0016	0016	0016	0016	0016	0015	0018	0016	0015	0016	0016
	0014	0016	0015	0016	0016	0016	0014	0017	0015	0016	0016	0017
	0016	0017	0015	0016	0015	0016	0016	0016	0015	0018	0015	0016
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	0015	0016	0016	0016	0014	0017	0015	0016	0017	0017	0014	0017
	0015	0018	0016	0017	0016	0018	0017	0022	0026	0036	0059	0083
	0090	0084	0060	0044	0039	0034	0027	0027	0024	0024	0021	0021
	0020	0020	0019	0020	0017	0019	0016	0018	0017	0018	0016	0018
	0017	0017	0016	0016	0016	0017	0015	0018	0015	0017	0015	0018
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Figure 2. Sample data parameter with received waveform output record generated from 25 October 2009 data. To see a larger version of this sample, please refer to Appendix A.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

As described on the NASA LVIS website, a laser altimeter is an instrument that measures range from the instrument to a target object or surface. The device sends a laser beam toward the target, and measures the time it takes for the signal to reflect back from the surface. Knowing the precise round-trip time it takes for the reflection to return yields the range to the target.

Figure 3 shows two examples of return energy waveforms. A simple waveform occurs where the ice surface is relatively smooth within the footprint of the laser pulse (approximately 20 meters in diameter). Mean noise level, provided with the Level-1B data product, provides the threshold relative to which the centroid and all modes are later computed for the Level-2 data product. A complex waveform might be returned from a rougher ice surface and could contain more than one mode, originating from different reflecting surfaces within the laser footprint such as crevasse sides and bottom, open water, large snowdrifts, and other steep or multiple slopes. A complex waveform would be more typically returned from multilevel vegetation landcover such as a forest.

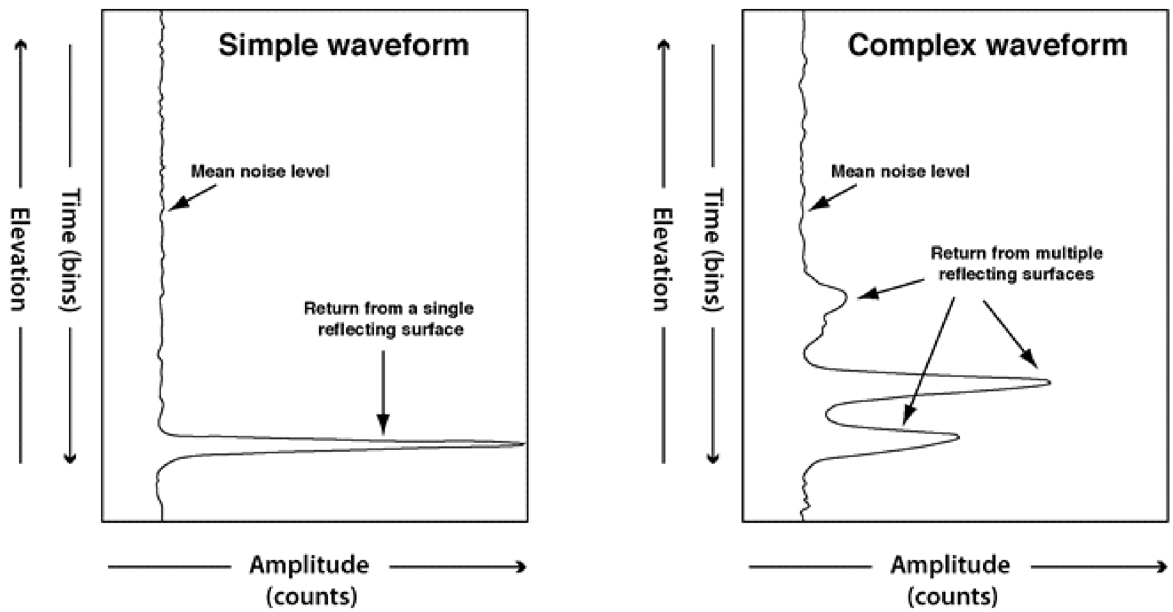

Figure 3 . Sample Level-1B product waveforms illustrating some possible distributions of reflected light.

2.2 Acquisition

The LVIS Level-1B Geolocated Return Energy Waveforms Product is generated from the raw instrument data as described under Processing Steps. More details can be found in Hofton et al. (2000).

2.3 Processing Steps

The following processing steps are performed by the data provider to produce the binary format Level-1B data.

1. The differential kinematic GPS data are post-processed to generate the airplane trajectory. The trajectory is merged with the laser data to produce the latitude, longitude, and altitude of the airplane for each laser shot.
2. An atmospheric correction is applied to each laser measurement. This adjustment is necessary due to effects of temperature and pressure on the speed of light through the atmosphere. It is computed using a model, and data extrapolated from the nearest meteorological station.
3. Laser pulse timing errors, due to the internal system response time and further affected by the amplitude of the return, are determined by calibration experiments. These are performed at the beginning and end of each flight. Each range measurement is corrected accordingly.
4. The attitude (roll, pitch, and yaw) of the airplane is recorded by the Inertial Navigation System (INS), and is interpolated for the time of each laser shot to know the precise pointing.

5. Several instrument biases are determined next. Timing biases are due to the delay between the actual observation of aircraft attitude and the recording of those data in the computer following the calculations. Laser mounting biases come from slight angular differences between the orientations of the three axes of the INS and those of the airplane. The timing and angle biases are determined after flying the airplane through controlled roll and pitch maneuvers over a known, preferably flat, surface.
6. The offset between the GPS antenna and the laser scan mirror must be known in order to relate the airplane trajectory and the range measurement. The offset vector is found by performing a static GPS survey between several system components inside and outside the grounded airplane.
7. The laser range measurement is transformed from a local reference system within the airplane to a global reference frame and ellipsoid. This creates the geolocated data product.

2.4 Instrumentation

2.4.1 Description

LVIS is an airborne LIDAR scanning laser altimeter used by NASA for collecting surface topography and vegetation coverage data. LVIS uses a signal digitizer with oscillator to measure transmitted and reflected laser pulse energies versus time capturing photon histories as waveforms. The laser beam and telescope field of view scan a raster pattern along the surface perpendicular to aircraft heading as the aircraft travels over a target area. LVIS has a scan angle of approximately 12 degrees and can cover 2 km swaths from an altitude of 10 km. Typical collection size is 10 to 25 meter spots. In addition to waveform data, GPS satellite data is recorded at ground tie locations and on the airborne platform to precisely reference aircraft position. An Inertial Measurement Unit (IMU) is attached directly to the LVIS instrument and provides information required for coordinate determination.

3 SOFTWARE AND TOOLS

3.1 Get Data

Version 1 binary data for 2012 and earlier campaigns are available via HTTPS.

IceBridge Portal: Tool to visualize, search, and download IceBridge data.

Version 2 HDF5 data beginning with the 2013 Arctic campaign are available via HTTPS.

3.2 Software and Tool Description

NSIDC provides an LVIS C reader that reads a binary data file from the Operation IceBridge LVIS instrument and prints the records to standard output. Note that the ASCII text results create very large output files.

4 VERSION HISTORY

On November 20 2012, the 2011 Antarctica LVIS Level 1B data were replaced with V01.1. The LVIS transmit laser waveform was improved in the 2011 Antarctica data.

Version 1 was retired in March 2024.

5 RELATED DATA SETS

- GLAS/ICESat L1B Global Elevation Data
- IceBridge LVIS L2 Geolocated Surface Elevation Product
- IceBridge ATM L1B Qfit Elevation and Return Strength
- Pre-IceBridge ATM L2 Icessn Elevation, Slope, and Roughness

6 RELATED WEBSITES

- LVIS webpage at NASA Goddard Space Flight Center
- IceBridge at NSIDC
- IceBridge at NASA
- ICESat/GLAS at NSIDC

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Blair, J. B., D. L. Rabine., and M. A. Hofton. 1999. The Laser Vegetation Imaging Sensor: A Medium-Altitude, Digitisation-Only, Airborne Laser Altimeter for Mapping Vegetation and Topography. ISPRS Journal of Photogrammetry and Remote Sensing, 54: 115-122. https://doi.org/10.1016/S0924-2716(99)00002-7

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Hofton, M. A., J. B. Blair, S. B. Luthcke, and D. L. Rabine. 2008. Assessing the Performance of 20-25 m Footprint Waveform Lidar Data Collected in ICESat Data Corridors in Greenland. Geophysical Research Letters, 35: L24501, https://doi.org/10.1029/2008GL035774

9 DOCUMENT INFORMATION

9.1 Publication Date

July 2012

9.2 Document Update Date

March 2024

APPENDIX A

0016	0014	0018	0015	0016	0016	0015	0016	0017	0013	0016	0015	0015
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Figure A-1. Sample data parameter without waveform output record generated from 25 October 2009 data.