IceBridge LVIS L1B Geolocated Return Energy Waveforms, Version 2

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. 2014, updated 2018. *IceBridge LVIS L1B Geolocated Return Energy Waveforms, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/RDT1MZVS0VG9. [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

1.1 File Information

1.1.1 Format

The Version 2 LVIS Level-1B Geolocated Return Energy Waveforms data files are in HDF5 format. Each data file is paired with an associated XML file, which contains additional metadata.

Note: Currently ILVIS1B data for 2009 through 2012 are in binary format stored separately as ILVIS1B Version 1. Beginning with the 2013 Arctic campaign, all data are provided in HDF5 format. For details on the Version 1 data, see the Version 1 documentation.

1.1.2 File Naming Convention

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

File name example:

```
ILVIS1B_GL2012_0505_R1210_063682.LGW4
```

```
ILVIS1B_GL2012_0505_R1210_063682.LGW4.xml
```

```
ILVIS1B_LOYYYY_MMDD_RYYMM_nnnnnn.xxx
```

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)

1.1.3 File Size

HDF5 data files range from approximately 61 MB to 913 MB. The total data file volume is approximately 2.5 TB.

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 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

1.2.1 Spatial Resolution

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

30 October 2013 to 20 September 2017

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 LVIS Level-1B files include geolocated return energy waveforms, transmitted waveform, and ancillary data.

1.4.1 Parameter Description

The HDF5 files contain fields as described in Table 2.

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
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

1.4.2 Sample Data Record

Below is an illustration of RXWAVE, LAT0, and LAT527 values from a sample of the `ILVIS1B_GL2013_1114_R1405_063767.h5` data file as displayed in the HDFView tool.

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.

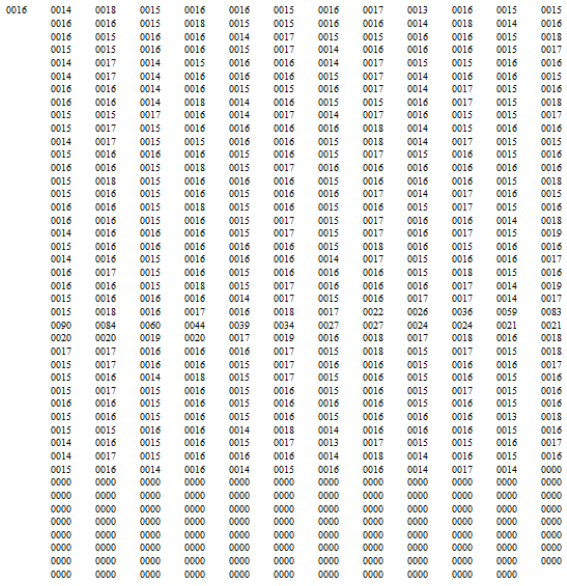

Figure 2. Sample data parameter with received waveform output record generated from 25 October 2009 data. To see a larger version of this sample, please refer to Appendix A.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

As described on the NASA LVIS Web site, 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 1 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.

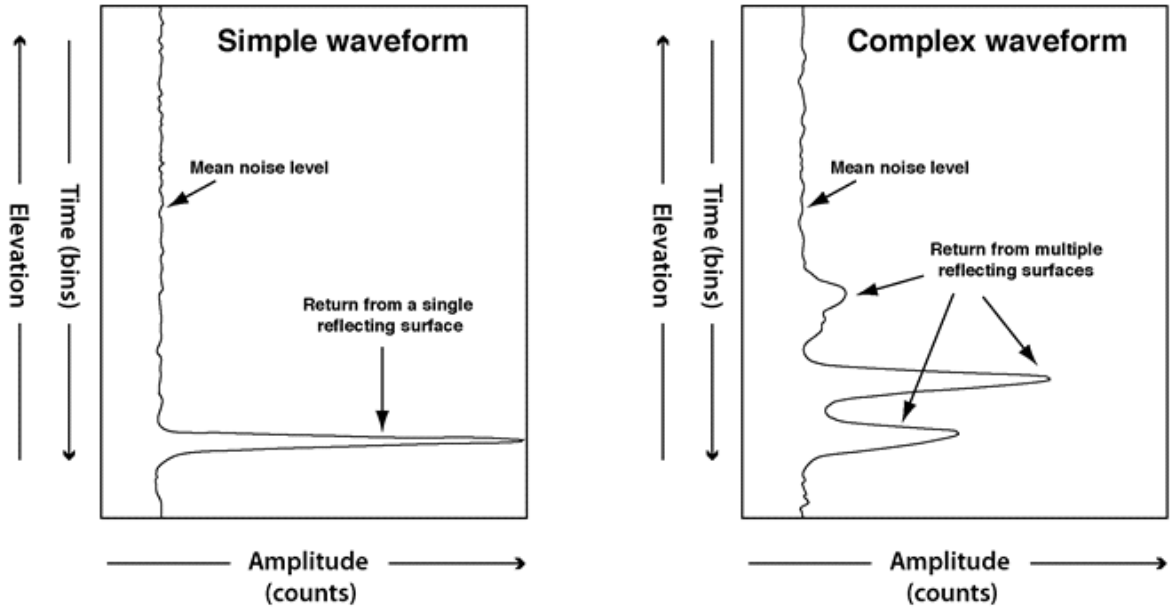

Figure 3 . Sample Level-1B product waveforms illustrating some possible distributions of reflected light.

2.2 Acquisition

LVIS employs a signal digitizer, disciplined with a very precise oscillator, to measure both the transmitted and reflected laser pulse energies versus time. These digitized and captured photon histories are known as waveforms. For the outgoing pulse, it represents the profile of the individual laser shot, and for the return pulse it records the interaction of that transmitted pulse with the target surface.

Processing of these waveforms yields many products, but the primary product is range from the instrument to the Earth's surface and the distribution of reflecting surfaces within the area of the laser footprint. For vegetated terrain these surfaces are tree canopies, branches, other forms of vegetation, and open ground. For cryospheric data these surfaces are snow, ice, crevasses, snowdrifts, and sea ice, possibly interspersed with open ocean, exposed rock, and water.

LVIS uses a waveform-based measurement technique to collect data instead of just timing detected returns of the laser pulse. The return signal is sampled rapidly, and stored completely for each laser shot. Retaining all waveform information allows post-processing of the data to extract many different products. With the entire vertical extent of surface features recorded, metrics can be extracted about the sampled area. An advantage of saving all of the waveform data is that new techniques can be applied to these data long after collection to extract even more information. See the NASA LVIS website.

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

As described on the NASA LVIS Web site the Land, Vegetation, and Ice Sensor (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

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.

- HDFView: Visual tool for browsing and editing HDF4 and HDF5 files.
- Panoply netCDF, HDF and GRIB Data Viewer: Cross-platform application. Plots geo-gridded arrays from netCDF, HDF and GRIB datasets.
- For additional tools, see the HDF-EOS Tools and Information Center.
- Also available: read_ilvis1b.pro, an IDL program that reads the LVIS Level-1B data into an IDL structure.

4 VERSION HISTORY

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

Version 2.0 of the ILVIS1B data: beginning with the 2013 Arctic campaign, all data are provided in HDF5 format.

For details on the Version 1 data, see the Version 1 documentation.

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 Web site at NASA Goddard Space Flight Center
- 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

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8 REFERENCES

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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, doi:10.1029/2008GL035774.

9 DOCUMENT INFORMATION

9.1 Publication Date

11 August 2014

9.2 Document Revision Date

13 June 2018

10 APPENDIX A – FIGURE 2

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
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Figure 4. Sample data parameter without waveform output record generated from 25 October 2009 data.