IceBridge LVIS-GH 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. 2015. *IceBridge LVIS-GH 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/D7ZJT02NGCC1. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ILVGH1B

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 File Information

1.1.1 Format

The LVIS-GH Level-1B Geolocated Return Energy Waveforms data files are in HDF5 format. Each data file is paired with an associated XML file. The XML files contain location, platform, and instrument metadata.

1.1.2 File Naming Convention

LVIS-GH Level-1B Geolocated Return Energy Waveforms data files are named according to the following conventions and as described in Table 1:

```
ILVGH1B_GL2013_1030_R1405_058062.h5
```

```
ILVGH1B_GL2013_1030_R1405_058062.h5.xml
```

```
ILVGH1B_LOYYYY_MMDD_RYYMM_TTTTTT.xxx
```

Table 1. File Naming Convention

Variable	Description
ILVGH1B	Short name for IceBridge LVIS-GH 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 (MM), two-digit Day (DD) of campaign
RYYMM	Release year (YY) and month (MM)
TTTTTT	Number of seconds since UTC midnight of the day the data collection started
xxx	Indicates LVIS-GH Geolocated Waveform file type: HDF5 (.h5), or XML (.xml)

1.1.3 File Size

HDF5 data files range from approximately 100 MB to 1 GB.

XML files range from approximately 10 KB to 58 KB.

1.1.4 Volume

Data volume for the full data set is approximately 315 GB.

1.2 Spatial Coverage

Spatial coverage for the IceBridge LVIS-GH campaigns include 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 15 meters, but varies with aircraft altitude. Laser footprint size is a function of beam divergence and altitude. Footprint spacing is a function of laser pulse repetition rate, the instrument field of view, and measurement requirements.

1.2.2 Projection and Grid Description

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

1.3 Temporal Coverage

These data were collected from 30 October 2013 to 14 November 2013 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, May, September, October, and November. Antarctic campaigns are conducted during October and November.

1.3.2 Parameter or Variable

The LVIS-GH Level-1B files include geolocated return energy waveforms.

1.3.3 Parameter Description

The LVIS-GH Level-1B HDF5 files are described in Table 2.

Table 2. Version 1.04 Parameter Description(HDF5 files)

Group	Parameter	Bytes	Type	Description	Units
/(root)	LVIS_LFID	4	Unsigned long integer	LVIS-GH 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. Together with LVIS_LFID provides a unique identifier to every LVIS-GH laser shot	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	Doublet	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

Group	Parameter	Bytes	Type	Description	Units
	SIGMEAN	4	Float	Signal mean noise level, calculated in-flight	Counts
	TXWAVE	120	Unsigned integer array	Transmitted waveform (120 samples)	Counts
	RXWAVE	528	Unsigned integer array	Received waveform (528 samples)	Counts
/ancillary_data/	HDF5 Version		Text	HDF version number	n/a
	Maximum Latitude		Text	Maximum value of latitude for this file	Degrees
	Maximum Longitude		Text	Maximum value of longitude for this file	Degrees
	Minimum Latitude		Text	Minimum value of latitude for this file	Degrees
	Minimum Longitude		Text	Minimum value of longitude for this file	Degrees
	Ancillary text		Text	Information about data set including platform, date collected, etc.	n/a
	Reference_frame		Text	Information about reference frame used for this file	n/a

1.3.4 Sample Data Record

Below is a graphed illustration of RANGE values in data file ILVGH1B_GL2013_1112_R1405_068936.h5.

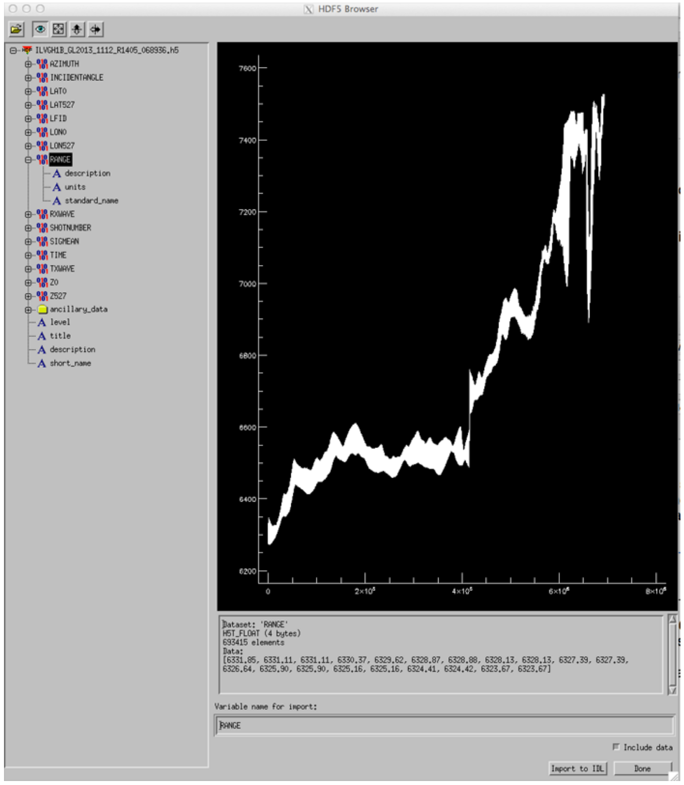

Figure 1. Sample Data. See Appendix A for a larger version.

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

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. The laser returned waveform, digitally-recorded by the sensor, provides a record of the vertical interaction of the laser pulse with the reflecting surfaces in the footprint. Information extracted from the return waveform allows the precise location of the reflecting surfaces to be derived. Knowing the precise round-trip time it takes for the reflection to return yields the range to the target.

Figure 2 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. Mean noise level, provided with the Level-1B data product, provides the threshold relative to which the elevation products are later computed for the Level-2 data. 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.

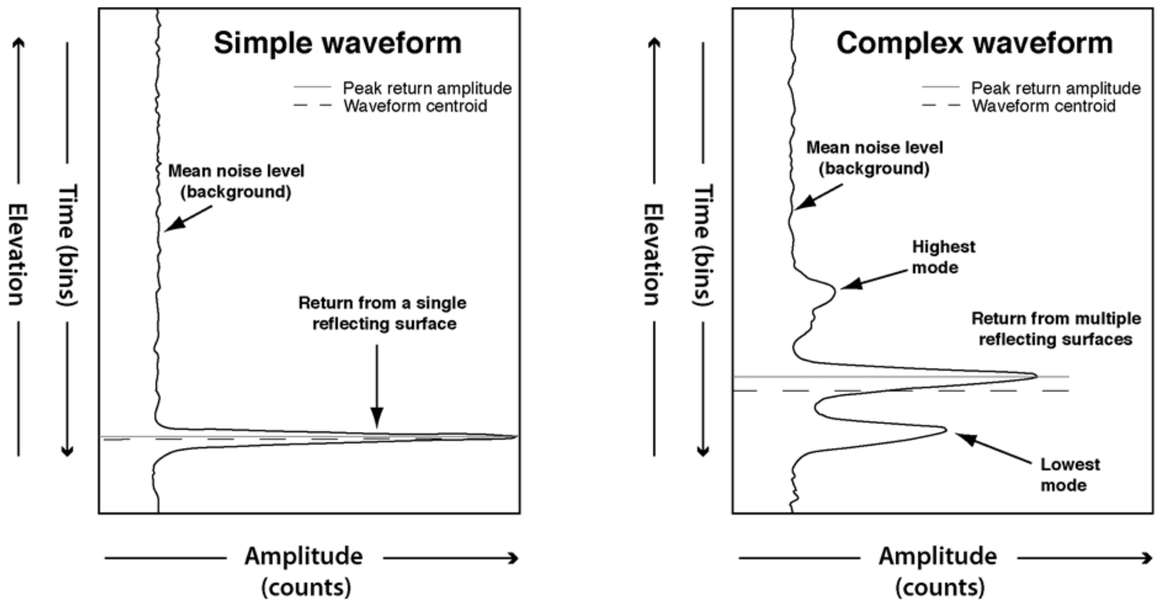

Figure 2. Sample Level-1B Product Waveforms Illustrating Distributions of Reflected Light.

2.2 Data Acquisition Methods

LVIS-GH employs three digitizers, disciplined with a single, 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 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, sea ice possibly interspersed with open ocean, exposed rock, and water.

LVIS-GH 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 Web site.

2.3 Derivation Techniques and Algorithms

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

2.3.1 Processing Steps

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

1. The GPS data are post-processed to generate the airplane trajectory. Precise Point Positioning (PPP) techniques are used. 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. 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.
4. Measurement model parameters are determined from airplane maneuvers performed during pre- and post-mission calibration flights and during science flights. Parameters include timing, rotational and translational offsets, for example, angular differences between the Inertial Measurement Unit (IMU) and laser pointing reference frames. The measurement model parameters are determined after flying the airplane through controlled maneuvers over a known, preferably flat, surface.
5. The laser range measurement, laser pointing, and laser positioning information are combined using the measurement model parameters to calculate the location of two reference points in each laser return waveform (referred to as bin 0 and bin 528) relative to a global reference frame. This creates the geolocated Level-1B data product. Further details can be found in Hofton et al. 2000.

2.4 Instrument Description

The Land, Vegetation, and Ice Sensor-Global Hawk (LVIS-GH) is an airborne LIDAR scanning laser altimeter developed by NASA for use in the Global Hawk Unmanned Aerial Vehicle (UAV) and available for install in other aircraft. This instrument is used primarily for collecting surface topography and 3D structure information. LVIS-GH uses a three digitizer system with a single 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-GH has scan angles of approximately 12 degrees, and can cover a 4 km swath from an altitude of 20 km. The nominal footprint size is 15 meters in diameter from an altitude of 20 km. In addition to waveform data, GPS satellite data is recorded at fixed ground locations and on the airborne platform to precisely reference aircraft position. An IMU is attached directly to the LVIS-GH instrument and provides information required for coordinate determination.

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.

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 data sets.

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

Also available: an IDL program that reads the LVIS-GH Level-1B data into an IDL structure: read_ilvis1b.pro.

4 VERSION HISTORY

Beginning with the 2013 Arctic campaign, all Level-1B data are provided in HDF5 format.

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

7 CONTACTS AND ACKNOWLEDGMENTS

Bryan Blair

Laser Remote Sensing Laboratory, Code 694

NASA Goddard Space Flight Center
Greenbelt, MD 20771

Michelle Hofton
Department of Geographical Sciences
2181 LeFrak Hall
University of Maryland
College Park, MD 20742

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8 REFERENCES

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Blair, J. B., et al. 2012. High-Altitude Laser Altimetry from the Global Hawk UAV for Regional Mapping of Surface Topography. AGU Fall Meeting Abstracts.

Hofton, M. A., J. B. Blair, J. B. Minster., J. R. Ridgway, N. P. Williams, J. L Bufton, and D. L. Rabine. 2000. An Airborne Scanning Laser Altimetry Survey of Long Valley, California, International Journal of Remote Sensing, 21(12): 2413-2437.

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

April 2015

9.2 Document Update Date

August 2016

10 APPENDIX A – FIGURE 1.

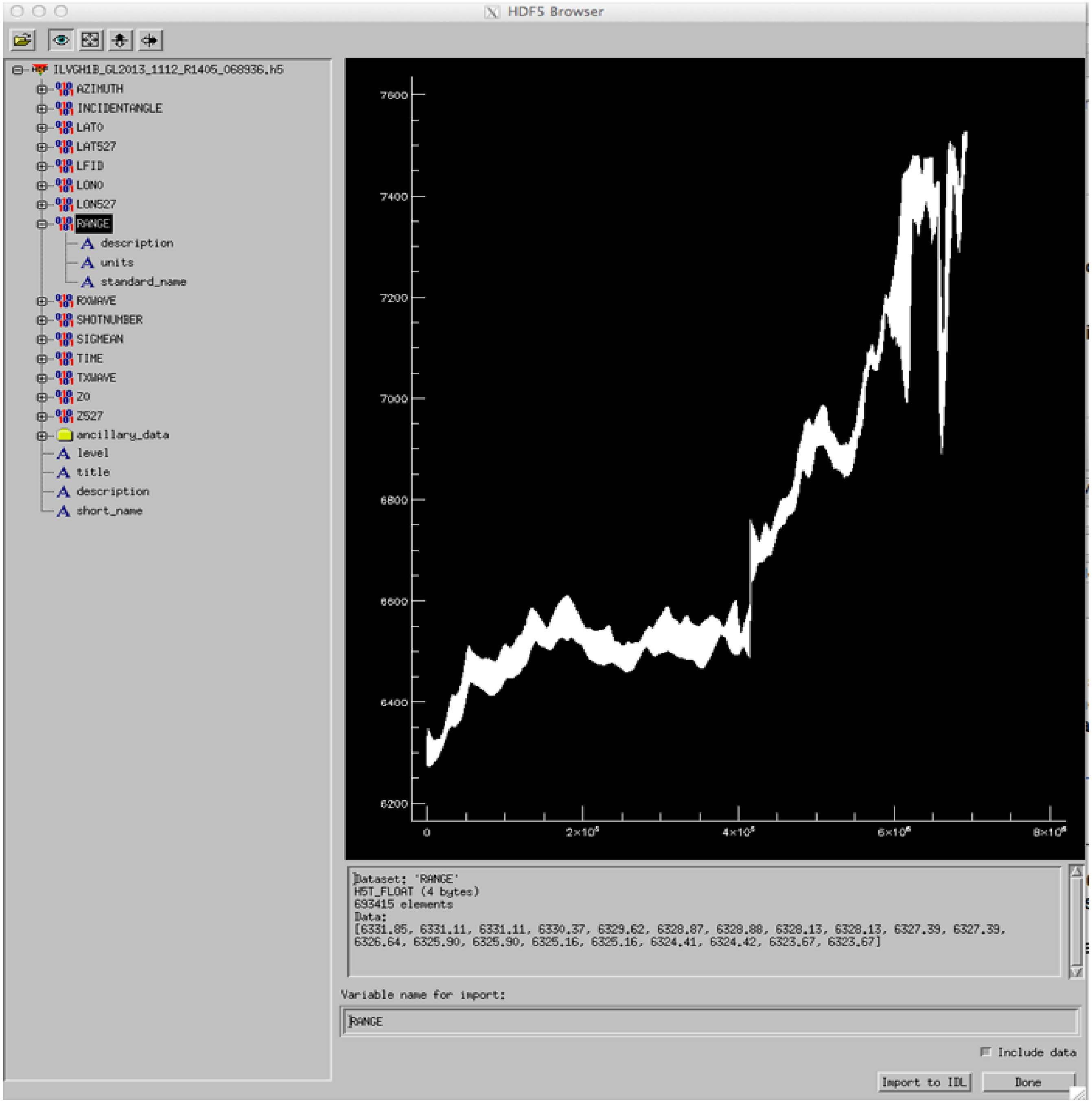

Figure 1. Sample Data