LVIS Facility 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. 2020. *LVIS Facility 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/XQJ8PN8FTIDG. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/LVISF1B

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This Level-1B data set contains measurements of geolocated return energy waveforms obtained by NASA's Land, Vegetation, and Ice Sensor (LVIS) Facility during several aircraft flight campaigns.

Two LVIS instruments are co-mounted and operated during flights, with data products referred to as LVISC (from the LVIS-Classic instrument) and LVISF (from the LVIS-Facility instrument). This data set contains measurements taken by the LVIS-Facility instrument, whereas the corresponding Level-1B LVISC data set, *LVIS Classic L1B Geolocated Return Energy Waveforms*, contains data from the co-mounted LVIS-Classic instrument. These two LVIS instruments differ in the laser footprint size and spacing on the ground. The laser used in the LVISF instrument also has a faster repetition rate and shorter pulse width than that used in the LVISC instrument. The Level-2 versions of these data sets, *LVIS Facility L2 Geolocated Surface Elevation and Canopy Height Product* and *LVIS Classic L2 Geolocated Surface Elevation and Canopy Height Product*, contain surface elevation measurements, canopy height measurements, and relative heights derived from the corresponding Level-1B data sets.

NOTE: This user guide refers to NASA's Land, Vegetation, and Ice Sensor (LVIS) Facility Technical Reference Document, Version 1 (LVIS Technical Reference), which contains a full list and descriptions of missions to date. This document can be found on the data set landing page under Documentation.

1.1 Parameters

All of the parameters contained in the data files are described in Table A-1 (see Appendix A).

1.2 File Information

1.2.1 Format

Data files are provided in HDF5 format (`.h5`). Each data file has an associated XML file (`.xml`) which contains additional science metadata.

1.2.2 Naming Convention

Files are named according to the following convention, which is described in Table 1.

```
LVISF1B_CAMPYYYY_MMDD_RYYMM_nnnnnn.ext
```

Example:

LVISF1B_ABoVE2019_0729_R2003_062749.h5

LVISF1B_ABoVE2019_0729_R2003_062749.h5.xml

Table 1. File Naming Convention

Variable	Description
LVISF1B	Data set ID
CAMPYYYY	Campaign identifier or primary location. Examples: ABoVE = Arctic-Boreal Vulnerability Experiment; GEDI = Global Ecosystem Dynamics Investigation; US = USA; GL = Greenland (see Section 1 File Naming Convention of the LVIS Technical Reference for a full list) YYYY = four-digit year of campaign
MMDD	Two-digit month, two-digit day of start of data collection
RYYMM	Date (YY year / MM month) of the data production. If data processing needs to be revised, the data production date is changed. Therefore, files with the latest production date are the most recent data revision.
nnnnnn	Number of seconds since GPS midnight of the day the data collection started
ext	Indicates file type: .h5 (HDF5 data file) or .h5.xml (XML metadata file)

1.2.3 Browse File

A PNG browse file, included with each granule, shows the waveform amplitude (counts) by elevation, as well as the geographic coordinates. An example is shown below:

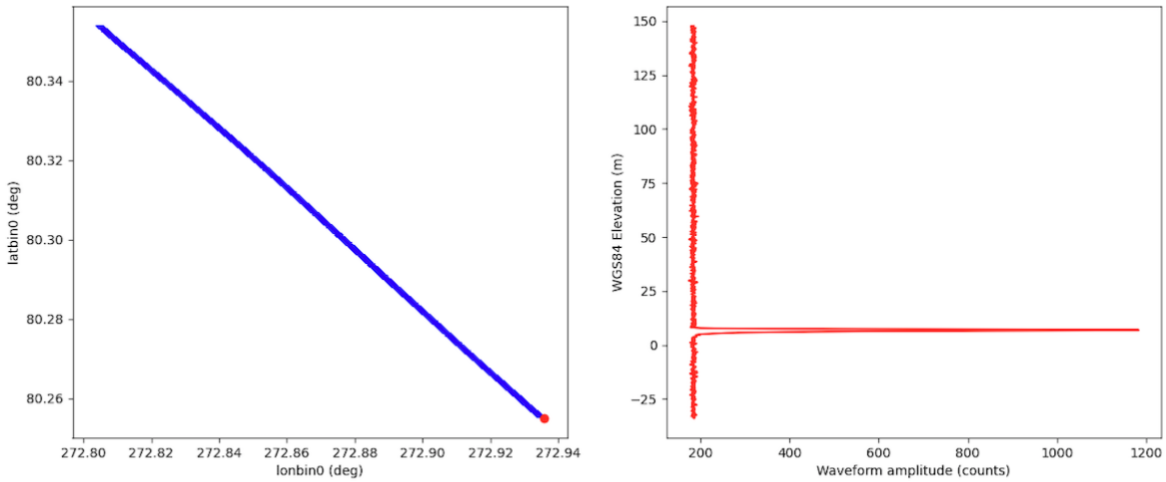

Figure 1. Example browse file.

Browse files have the same naming convention as the corresponding .h5 file but with "browse" appended.

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage for this data set currently has the following extent:

Southernmost latitude: 35° S
Northernmost latitude: 88° N
Westernmost longitude: 167° W
Easternmost longitude: 27° E

For more details on campaign-specific spatial coverage, see the LVIS Technical Reference.

1.3.2 Resolution

The spatial resolution (footprint spacing) of the LVISF data sets is chosen with consideration of science goals and is a function of laser rate, aircraft ground speed, and operator settings. For example, the nominal spatial resolution may be 10 m in both the along- and across-track directions for a slower aircraft at a 10 km flight altitude. Data can be spaced closer or further apart in the across- and along-track directions depending on user goals. Laser footprint size is a function of beam divergence and altitude.

1.3.3 Geolocation

Table 2. Geolocation Details

Geographic coordinate system	WGS 84	WGS 84
Prime Meridian	0°	0°
Datum	World Geodetic System 1984 ensemble	ITRF 2008
Ellipsoid/spheroid	WGS 84	GRS 1980
Units	degrees	meters
EPSG codes	4326	5332
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs	+proj=geocent +ellps=GRS80 +units=m +no_defs +type=crs
Reference	https://epsg.io/4326	https://epsg.io/5332

1.4 Temporal Information

1.4.1 Coverage

7 November 2018 to present

For information on campaign dates, see the LVIS Technical Reference.

1.4.2 Resolution

Varies

2 INSTRUMENTATION

NASA's LVIS Facility is an imaging lidar and camera sensor suite for precise and accurate large-area surface mapping and characterization. The Facility uses airborne lidar scanning laser altimeters to collect elevation and 3D surface structure information over land, ocean, and ice surfaces, along with downward-looking, high-resolution camera imagery. The LVIS instruments differ in laser footprint size and spacing on the ground but generate near-identical data products.

Laser altimeters send a laser beam toward a target object and measure the time it takes for the signal to reflect back from the surface. Knowing the precise round-trip time for the reflection to return allows the distance, or range, to the target to be calculated. Range is combined with the pointing and positioning of the laser at the time of each laser shot to determine the location of each laser footprint on the ground relative to a reference ellipsoid (e.g., Hofton et al. 2000). LVIS employs a signal digitizer with a very precise oscillator to measure both the transmitted and reflected laser pulse energies versus time. These digitized and captured histories are known as waveforms (i.e., the transmitted and return waveforms). The outgoing signal represents the profile of the individual laser pulse versus time; the return pulse comprises the interaction of that transmitted pulse with the target surface versus time.

As the aircraft travels over a target area, the laser beam and the telescope field-of-view scan a pattern along the surface perpendicular to the aircraft heading. LVIS instruments have a scan angle of approximately 12° (±6° around nadir), allowing them to cover 2 km swaths from an altitude of 10 km. The typical diameter of the laser footprint on the ground is 7 m to 25 m, depending on the aircraft altitude, as well as laser repetition rate and beam divergence. Laser positioning at the time of each laser shot is provided by GPS satellite data. Laser pointing information is provided by an Inertial Measurement Unit (IMU) attached directly to the LVIS instrument.

3 DATA ACQUISITION AND PROCESSING

3.1 Background

Figure 2 shows two examples of return waveforms: a simple waveform (left) and a complex waveform (right). The simple waveform occurs when the surface is relatively smooth within the laser footprint, thus generating a laser return waveform that consists of a single mode. The detection threshold is computed relative to the mean noise level and is used to detect the return signals that are geolocated for Level-2 data products. Complex waveforms containing more than one mode are produced when the laser beam hits multilayered surfaces, such as forests, vegetated land cover, ice crevasses, or rocky terrain. Different modes represent the various surfaces within the footprint, such as the canopy top, the ground, the crevasse bottom, or the top of broken ice surface, and are distributed according to their relative elevations within the footprint.

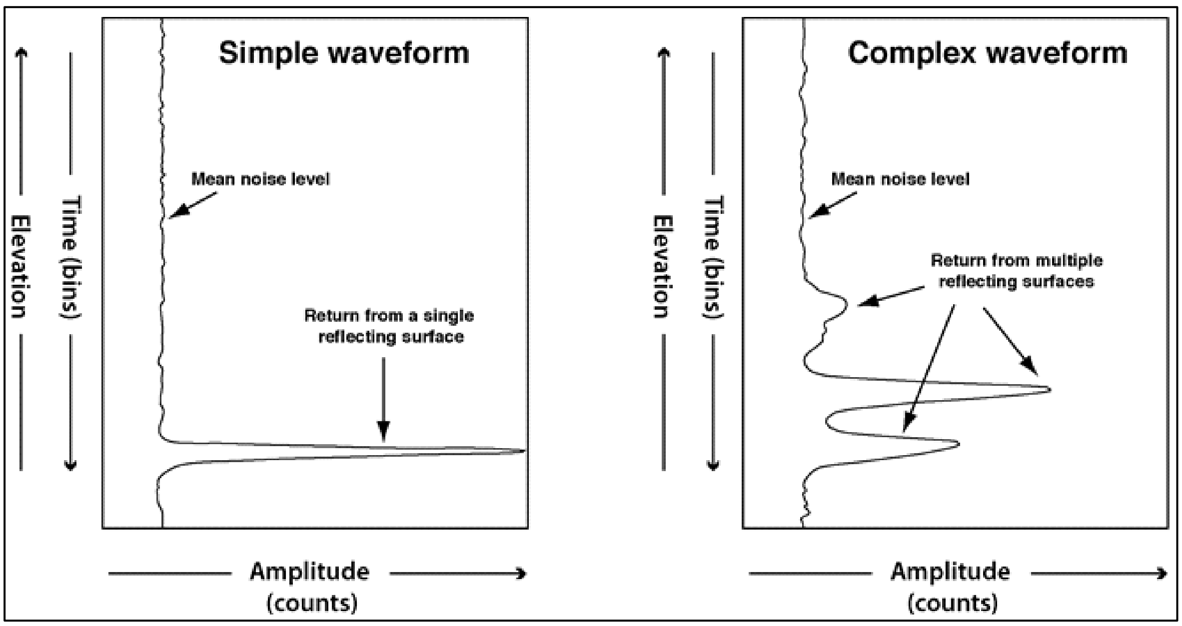

Figure 2. Sample Level-1B product waveforms illustrating possible distributions of reflected light.

3.2 Acquisition

The primary Level-1B data product is the geolocated laser return waveforms (RXWAVE, LON0, LON1215, LAT0, LAT1215, Z0, and Z1215 in Table A-1), representing the vertical distribution of reflecting surfaces within the area of the laser footprint over the sampled terrain relative to a global reference frame and ellipsoid. For vegetated terrain, these surfaces include tree canopies, branches, other forms of vegetation, and open ground. For cryospheric areas, these surfaces comprise 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 only 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 many different products to be extracted during data post-processing, such as the data presented in the Level-2 data products. With the entire vertical extent of surface features recorded and geolocated relative to a global reference frame, metrics can be extracted about the sampled area. An advantage of saving and georeferencing all of the waveform data is that new techniques can be applied to these data long after collection to extract additional information. See the LVIS website at NASA Goddard Space Flight Center for more information.

3.3 Processing Steps

This data set is generated from raw, Level-0 instrument data. The following processing steps are performed by the data provider to produce the Level-1B data:

1. The GPS and IMU data are post-processed to generate the airplane positioning and pointing information. These data streams can be processed in multiple ways, such as differential kinematic or precise point positioning GPS that are loosely or tightly coupled with the IMU data. The resulting positioning and attitude data are then merged with the laser data to produce the latitude, longitude, altitude, roll, pitch, and heading of the airplane for each laser shot.
2. The laser range measurement is calculated based on the travel time of the laser pulse from the laser reference frame origin to the surface. The range is adjusted for delays associated with internal system responses (e.g., cabling lengths), which are determined by calibration experiments that are typically performed in the lab before the mission. An atmospheric correction is also applied to each laser measurement. This adjustment is necessary because temperature and pressure affect the speed of light through the atmosphere. The correction is computed using a model and data extrapolated from the nearest meteorological station. Additional checks to a target surface of known elevation may be performed during a flight.
3. Measurement model parameters to align the various reference frames are determined. These include angular offsets between the IMU and laser reference frames, translation to relocate the GPS measurements at the laser reference frame origin, and timing biases between the IMU and the laser. Estimates for angular measurement model parameters can be determined by flying the airplane through controlled roll and pitch maneuvers over a known, preferably flat, surface. The offset between the GPS antenna and the laser reference frame origin is found by performing a static GPS survey between several system components inside and outside the grounded airplane.
4. The laser position and pointing vectors as well as the measurement parameters are input to the measurement model to transform the laser range from a local reference system within the airplane to a global reference frame and ellipsoid, thus creating a geolocated data product.

For more details, see Hofton et al. (2000).

3.4 Quality, Errors, and Limitations

Obvious lower quality data, such as data collected in areas with clouds and cloud-obscured returns, were removed; however, spurious returns may still be present. Data collected during aircraft turns have been removed from this data set. It is recommended that users review the waveforms for their specific areas of study to verify ground return and canopy top identification. It is possible that some anomalies are still present in the data.

4 RELATED DATA SETS

LVIS Facility L2 Geolocated Surface Elevation and Canopy Height Product (LVISF2)
LVIS Classic L1B Geolocated Return Energy Waveforms (LVISC1B)
LVIS Classic L2 Geolocated Surface Elevation and Canopy Height Product (LVISC2)
ABoVE LVIS L1B Geolocated Return Energy Waveforms (ABLVIS1B)
ABoVE LVIS L2 Geolocated Surface Elevation Product (ABLVIS2)
AfriSAR LVIS L1B Geolocated Return Energy Waveforms (AFLVIS1b)
AfriSAR LVIS L2 Geolocated Surface Elevation Product (AFLVIS2)
LVIS L1A Geotagged Images (OLVIS1A)

5 RELATED WEBSITES

LVIS website at NSIDC
LVIS website at NASA Goddard Space Flight Center

6 ACKNOWLEDGMENTS

See the LVIS Technical Reference for a complete list of acknowledgments.

7 REFERENCES

Hofton, M. A., Blair, J. B., Minster, J.-B., Ridgway, J. R., Williams, N. P., Bufton, J. L., & Rabine, D. L. (2000). An airborne scanning laser altimetry survey of Long Valley, California. *International Journal of Remote Sensing*, *21*(12), 2413–2437. https://doi.org/10.1080/01431160050030547

8 DOCUMENT INFORMATION

8.1 Publication Date

March 2020

8.2 Date Last Updated

May 2024

APPENDIX A – DATA FILE PARAMETERS

Table A-1. HDF5 File Parameters

Group	Parameter	Description	Units
/(root)	LFID	LVIS file identification. The format is XXYYYYYZZZ, where XX identifies instrument version, YYYYY is the Modified Julian Date of the flight departure day, and ZZZ represents the file number.	N/A
	SHOTNUMBER	LVIS shot number assigned during collection. Together with LFID, it provides a unique identifier to every LVIS laser shot.	N/A
	AZIMUTH	Azimuth angle of laser beam	Degrees
	INCIDENTANGLE	Off-nadir incident angle of laser beam	Degrees
	RANGE	Distance along laser path from the instrument to the ground	Meters
	TIME	GPS time; equal to UTC at midnight on 6 January 1980	Seconds
	LON0	Longitude of the highest sample of the return waveform	Degrees East
	LAT0	Latitude of the highest sample of the return waveform	Degrees North
	Z0	Elevation of the highest sample of the waveform with respect to the reference ellipsoid	Meters
	LON1215	Longitude of the lowest sample of the return waveform	Degrees East
	LAT1215	Latitude of the lowest sample of the return waveform	Degrees North
	Z1215	Elevation of the lowest sample of the waveform with respect to the reference ellipsoid	Meters
	SIGMEAN	Signal mean noise level, calculated in-flight	Counts
	TXWAVE	Transmitted waveform, 128 bins long, 12 bits at 1GHz	Counts
	RXWAVE	Return waveform, 1024 bins long, 12 bits at 1GHz	Counts
/ancillary_data/	HDF5 Version	HDF5 version number based on IDL version	Number

Group	Parameter	Description	Units
	Maximum Latitude	Maximum value of latitude to be found in this file	Degrees North
	Maximum Longitude	Maximum value of longitude to be found in this file	Degrees East
	Minimum Latitude	Minimum value of latitude to be found in this file	Degrees North
	Minimum Longitude	Minimum value of longitude to be found in this file	Degrees East
	ancillary_text	Ancillary information relevant to data collection and processing	N/A
	reference_frame	Reference frame for LVIS data products, derived from reference frame for global navigation satellite system (GNSS) orbits	N/A