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

TABLE OF CONTENTS

1 DATA DESCRIPTION

This Level-1B data set contains measurements taken by NASA's Land, Vegetation, and Ice Sensor (LVIS) in support of the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) and the NASA Global Ecosystem Dynamics Investigation (GEDI). Additional data are available from annual Engineering Check Flights of the LVIS instrument obtained over sites in Maryland, Virginia, and North Carolina.

ABoVE is a NASA Terrestrial Ecology Program conducted in Alaska and Western Canada. The ABoVE data are used to study environmental change and its implications for social-ecological systems. GEDI was launched to the International Space Station (ISS) in December 2018 to measure forest canopy height, structure, and surface elevation to improve characterization of important carbon and water cycle processes, biodiversity, and habitats. These flights provide data for ABoVE science investigations, as well as calibration and validation of GEDI mission in the United States, Canada, and Central America.

Engineering Check Flights were flown in the United States on 07 November 2018 and 31 January 2019 out of NASA's Langley Research Center in Hampton, VA.

Two LVIS instruments were 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 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.

This data set is also closely related to the *ABoVE LVIS L1B Geolocated Return Energy Waveforms* data set, which provides ABoVE data, and the *AfriSAR LVIS L1B Geolocated Return Energy Waveforms* data set, which provides GEDI calibration and validation data.

1.1 Parameters

All of the parameters contained in the data files are described in Table 1.

Table 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	UTC decimal seconds of the day	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
	Maximum Latitude	Maximum value of latitude to be found in this file	Degrees North

Group	Parameter	Description	Units
	`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. Using International Terrestrial Reference Frame 2008 (ITRF08).	

Notes:

(*) These parameter names are different from the ones in the *LVIS Classic L1B Geolocated Return Energy Waveforms* data set.

(**) The descriptions of these parameters are slightly different from the ones in the *ABoVE LVIS L1B Geolocated Return Energy Waveforms* and the *LVIS Classic L1B Geolocated Return Energy Waveforms* data sets.

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

Example file names:

LVISF1B_ABoVE2019_0729_R2003_062749.h5
LVISF1B_ABoVE2019_0729_R2003_062749.h5.xml

LVISF1B_GEDI2019_0521_R2003_073519.h5
LVISF1B_GEDI2019_0521_R2003_073519.h5.xml

LVISF1B_US2018_1107_R2011_067463.h5

LVISF1B_US2018_1107_R2011_067463.h5.xml

Files are named according to the following convention, which is described in Table 2:

LVISF1B_CAMPYYYY_MMDD_RYYMM_nnnnnn.ext

Table 2. File Naming Convention

Variable	Description
LVISF1B	Data set ID
CAMPYYYY	Campaign identifier: ABoVE = Arctic-Boreal Vulnerability Experiment; GEDI = Global Ecosystem Dynamics Investigation; US = Engineering Check Flights; 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
nnnnnn	Number of seconds since UTC midnight of the day the data collection started
ext	Indicates file type: .h5 (HDF5 data file) or .h5.xml (XML metadata file)

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage for this data set currently includes parts of Alaska, Western Canada, the continental United States, and central America, as noted by the spatial extents below:

Southernmost latitude: 9° N

Northernmost latitude: 72° N

Westernmost longitude: 168° W

Easternmost longitude: 75° W

1.3.2 Resolution

The nominal spatial resolution of the LVISF data sets is 10 m, but varies slightly with aircraft altitude and speed. Laser spot size is a function of beam divergence and altitude. Nominal spot spacing is a function of scan rate, pulse repetition rate, and airplane ground speed.

1.3.3 Geolocation

International Terrestrial Reference Frame 2008 (ITRF08), WGS-84 ellipsoid

1.4 Temporal Information

1.4.1 Coverage

7 November 2018 to 08 August 2019

1.4.2 Resolution

Varies

2 INSTRUMENTATION

NASA's LVIS is an imaging lidar sensor suite for precise and accurate large-area surface mapping and characterization. LVIS uses airborne lidar scanning laser altimeters to collect topography and vegetation coverage data 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 10 m to 25 m, depending on the aircraft altitude, as well as laser repetition rate and 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 1 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.

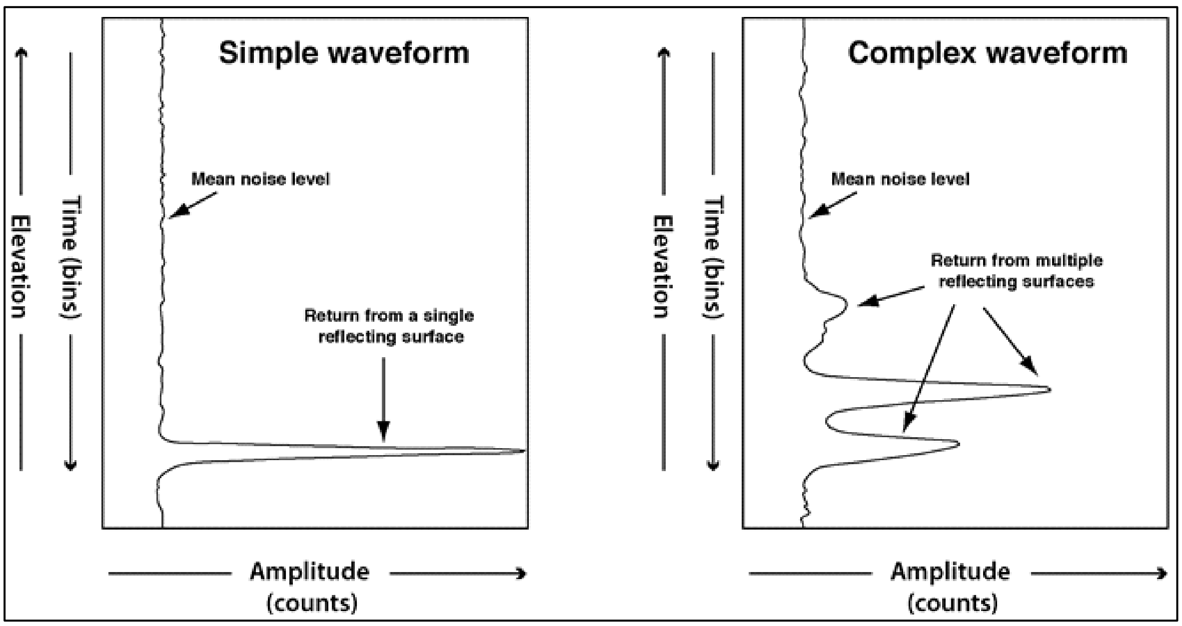

Figure 1. Sample Level-1B product waveforms illustrating possible distributions of reflected light.

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 1), representing the vertical distribution of reflecting surfaces within the area of the laser footprint over the sampled terrain. 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 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 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, 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 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 PPP 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 in 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 SOFTWARE AND TOOLS

The data files can be opened by any software that reads HDF5 files, such as HDFView and Panoply.

5 RELATED DATA SETS

LVIS Facility L2 Geolocated Surface Elevation and Canopy Height Product
LVIS Classic L1B Geolocated Return Energy Waveforms
LVIS Classic L2 Geolocated Surface Elevation and Canopy Height Product
ABoVE LVIS L1B Geolocated Return Energy Waveforms
ABoVE LVIS L2 Geolocated Surface Elevation Product
AfriSAR LVIS L1B Geolocated Return Energy Waveforms
AfriSAR LVIS L2 Geolocated Surface Elevation Product

6 RELATED WEBSITES

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

7 CONTACTS

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9 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

10 DOCUMENT INFORMATION

10.1 Publication Date

March 2020

10.2 Date Last Updated

February 2021