LVIS Facility L2 Geolocated Surface Elevation and Canopy Height Product, Version 1

USER GUIDE

How to Cite These Data

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

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/LVISF2

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This Level-2 data set contains surface elevation and canopy heights derived from LVIS Facility L1B Geolocated Return Energy Waveforms (LVISF1B).

Two Land, Vegetation, and Ice Sensor (LVIS) instruments may be 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-2 LVISC data set, *LVIS Classic L2 Surface Elevation and Canopy Height Products*, contains data from the co-mounted LVIS-Classic instrument if it was operated. These two LVIS instruments differ in 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-1B versions of these data sets, *LVIS Facility L1B Geolocated Return Energy Waveforms* and *LVIS Classic L1B Geolocated Return Energy Waveforms*, contain geolocated return energy waveforms measured by the LVIS sensors from which these Level-2 product files are directly derived.

NOTE: This user guide refers to NASA's 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 Appendices A and B.

1.2 File Information

1.2.1 Format

The data files are in ASCII text format (`.TXT`). Each data file is paired with an associated XML file (`.xml`), which contains additional metadata.

1.2.2 File Content

The data files contain multiple elevations and their corresponding latitude and longitude locations, relative surface heights, and 3D surface metric products that correspond to distinct reflecting surfaces (if they exist) within each laser footprint that were derived from the corresponding laser return waveforms. The files are labeled as either land (including water) surface or ice (e.g., land or sea ice) surface data; thus, there are two file naming conventions. The parameters are described in Appendix A (land surface) and Appendix B (ice surface).

1.2.3 Naming Convention

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

Ice surface files:

LVISF2_IS_CAMPYYYY_MMDD_RYYMM_nnnnnn.ext

Example:

LVISF2_IS_GL2022_0422_R2212_044224.TXT

LVISF2_IS_GL2022_0422_R2212_044224.TXT.xml

Land surface files:

LVISF2_CAMPYYYY_MMDD_RYYMM_nnnnnn.ext

Example:

LVISF2_GL2022_0727_R2212_057999.TXT

LVISF2_GL2022_0727_R2212_057999.TXT.xml

Table 1. File Naming Convention

Variable	Description
`LVISF2`	LVIS Facility L2 Geolocated Surface Elevation and Canopy Height Product
`IS`	Ice surface data; file names *without* this variable contain land surface data
`CAMPYYYY`	Campaign identifier or primary location. Examples: ABoVE = Arctic-Boreal Vulnerability Experiment; GEDI = Global Ecosystem Dynamics Investigation; US = USA; GL = Greenland (see 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: `.txt` (ASCII text data file) or `txt.xml` (XML metadata file)

1.2.4 Browse File

A .PNG file, included with each granule, shows the geographic location of the data colored by elevation (top) and the distribution of surface elevation within the Level-2 file (bottom).

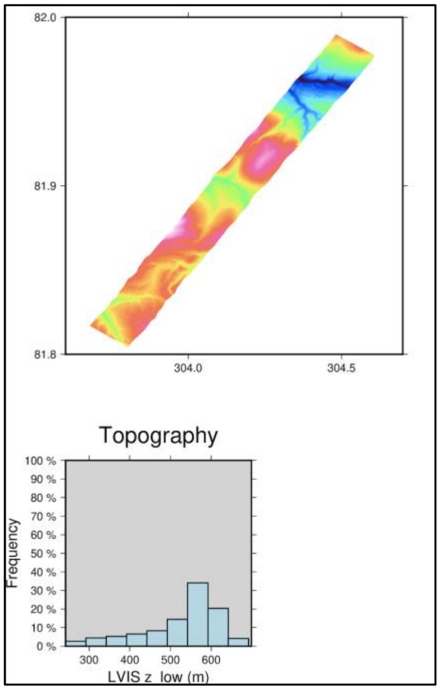

Figure 1. Example browse image.

Browse files have the same naming convention as the corresponding .TXT 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 to science goals and is a function of laser rate, aircraft ground speed, and operator settings. For example, the nominal spatial resolution of data can be 10 m in both the along- and across-track directions when using a slower aircraft at a 10 km flight altitude. Data can be spaced closer or farther 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.

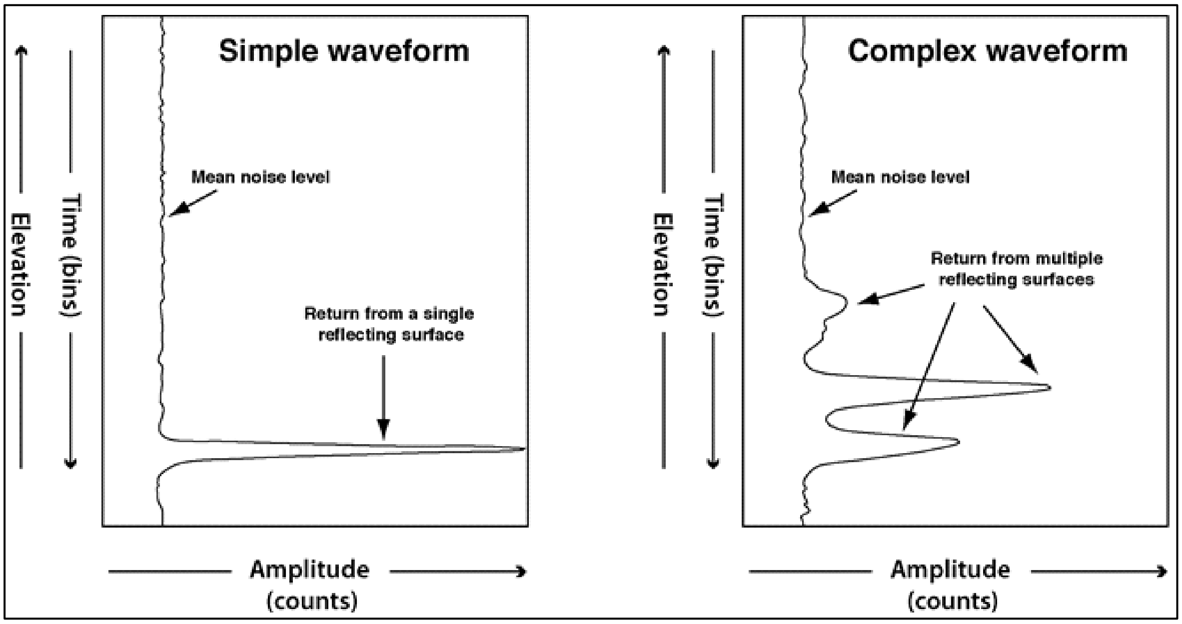

Figure 2. Sample Level-1B product waveforms illustrating possible distributions of reflected light.

3.2 Acquisition

The primary Level-1B data product is the geolocated laser return waveforms, 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 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.

3.3 Processing Steps

This data set is derived from the Level-1B data set, *LVIS Facility L1B Geolocated Return Energy Waveforms*. The following processing steps are performed by the data provider to produce the Level-2 data:

1. Establish noise threshold settings to be applied to the Level-1B waveform data, then establish the area within each laser return waveform to search for surface signals.
2. De-noise (smooth) the laser return waveform by convolution with a Gaussian function.
3. Determine surface timing/ranging points (e.g., lowest, highest detected signals, center of each reflected mode) and energy metric locations relative to the start of each laser return waveform.
4. Linearly interpolate the geolocation information provided in the Level-1B data to the surface timing/ranging points determined in step 3 to generate the geolocation of the Level-2 data products. Relative height products are then computed relative to the elevation of the lowest detected mode.

For more details, see Hofton et al. (2000) and Hofton and Blair (2019).

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. Atmospheric conditions (fog, haze, and blowing snow) in sections of flights can cause multiple scattering, which can appear as a tail in the return waveforms. 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 surface return identification. It is possible that some anomalies are still present in the data.

4 VERSION HISTORY

Table 3. Version History Summary

Version	Date Implemented	Impacted Temporal Coverage	Description of Changes
v1.1	8 Apr 2024	17 May to 16 Aug 2024	Added data for ARCSIX 2024 campaign
v1.1	25 Mar 2025	26 Jun to 3 Jul 2024	Added data for SARP 2024 campaign
v1.1	23 Oct 2024	26 Feb to 1 Mar 2024	Added data for ICESat-2 Lake Ice campaign
v1.1	15 Oct 2024	April 2022	Data files for the Greenland Spring 2022 campaign (19 April and 22 April) were reprocessed to implement a vertical calibration adjustment. The "production date" in the file names changed from R2210 to R2408. Data were also added for 21 April and 25 April.
v1.0	21 May 2020	7 Nov 2018 to present	Initial release

5 RELATED DATA SETS

LVIS Facility L1B Geolocated Return Energy Waveforms (LVISF1B)

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)

IceBridge LVIS L1B Geolocated Return Energy Waveforms (ILVIS1B)

IceBridge LVIS L2 Geolocated Surface Elevation Product (ILVIS2)

6 RELATED WEBSITES

LVIS website at NSIDC

LVIS website at NASA Goddard Space Flight Center

7 ACKNOWLEDGMENTS

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

8 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

Hofton, M. A., & Blair, J. B. (2019). Algorithm Theoretical Basis Document for GEDI Transmit and Receive Waveform Processing for L1 and L2 Products. https://lpdaac.usgs.gov/documents/581/GEDI_WF_ATBD_v1.0.pdf

9 DOCUMENT INFORMATION

9.1 Publication Date

March 2020

9.2 Date Last Updated

April 2025

APPENDIX A – LAND SURFACE FILE PARAMETERS

Table A-1. ASCII Text File Parameters for Land Surface Data

Parameter	Description	Units
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
TIME	UTC decimal seconds of the day	seconds
GLON	Longitude of the lowest detected mode within the waveform	degrees east
GLAT	Latitude of the lowest detected mode within the waveform	degrees north
ZG	Mean elevation of the lowest detected mode within the waveform	meters
ZG_ALT1	Mean elevation of the lowest detected mode within the waveform using alternate 1 mode detection settings	meters
ZG_ALT2	Mean elevation of the lowest detected mode within the waveform using alternate 2 mode detection settings	meters
HLON	Longitude of the center of the highest detected mode within the waveform	degrees east
HLAT	Latitude of the center of the highest detected mode within the waveform	degrees north
ZH	Mean elevation of the highest detected mode within the waveform	meters
TLON	Longitude of the highest detected signal	degrees east
TLAT	Latitude of the highest detected signal	degrees north
ZT	Elevation of the highest detected signal	meters
RH10	Height (relative to ZG) at which 10% of the waveform energy occurs	meters
RH15	Height (relative to ZG) at which 15% of the waveform energy occurs	meters
RH20	Height (relative to ZG) at which 20% of the waveform energy occurs	meters
RH25	Height (relative to ZG) at which 25% of the waveform energy occurs	meters
RH30	Height (relative to ZG) at which 30% of the waveform energy occurs	meters

Parameter	Description	Units
RH35	Height (relative to ZG) at which 35% of the waveform energy occurs	meters
RH40	Height (relative to ZG) at which 40% of the waveform energy occurs	meters
RH45	Height (relative to ZG) at which 45% of the waveform energy occurs	meters
RH50	Height (relative to ZG) at which 50% of the waveform energy occurs	meters
RH55	Height (relative to ZG) at which 55% of the waveform energy occurs	meters
RH60	Height (relative to ZG) at which 60% of the waveform energy occurs	meters
RH65	Height (relative to ZG) at which 65% of the waveform energy occurs	meters
RH70	Height (relative to ZG) at which 70% of the waveform energy occurs	meters
RH75	Height (relative to ZG) at which 75% of the waveform energy occurs	meters
RH80	Height (relative to ZG) at which 80% of the waveform energy occurs	meters
RH85	Height (relative to ZG) at which 85% of the waveform energy occurs	meters
RH90	Height (relative to ZG) at which 90% of the waveform energy occurs	meters
RH95	Height (relative to ZG) at which 95% of the waveform energy occurs	meters
RH96	Height (relative to ZG) at which 96% of the waveform energy occurs	meters
RH97	Height (relative to ZG) at which 97% of the waveform energy occurs	meters
RH98	Height (relative to ZG) at which 98% of the waveform energy occurs	meters
RH99	Height (relative to ZG) at which 99% of the waveform energy occurs	meters
RH100	Height (relative to ZG) at which 100% of the waveform energy occurs	meters
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
COMPLEXITY	Complexity metric for the return waveform	N/A

Parameter	Description	Units
SENSITIVITY	Sensitivity metric for the return waveform	N/A
CHANNEL_ZT	Flag indicating LVIS channel waveform contained in the Level-1B file	N/A
CHANNEL_ZG	Flag indicating LVIS channel used to locate ZG	N/A
CHANNEL_RH	Flag indicating LVIS channel used to calculate RH metrics	N/A

APPENDIX B – ICE SURFACE FILE PARAMETERS

Table B-2. ASCII Text File Parameters for Ice Surface Data

Parameter	Description	Units
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
TIME	UTC decimal seconds of the day	Seconds
LON_LOW	Longitude of the lowest detected mode within the waveform	degrees east
LAT_LOW	Latitude of the lowest detected mode within the waveform	degrees north
Z_LOW	Mean elevation of the lowest detected mode within the waveform	meters
LON_MAXAMP	Longitude of the peak mode within the waveform	degrees east
LAT_MAXAMP	Latitude of the peak mode within the waveform	degrees north
Z_MAXAMP	Mean elevation of the peak mode within the waveform	meters
LON_HIGH	Longitude of the highest detected mode within the waveform	degrees east
LAT_HIGH	Latitude of the highest detected mode within the waveform	degrees north
Z_HIGH	Mean elevation of the highest detected mode within the waveform	meters
LON_LOW_ALT	Alternate lowest mode location, based on lower signal detection threshold	degrees east
LAT_LOW_ALT	Alternate lowest mode location, based on lower signal detection threshold	degrees north
Z_LOW_ALT	Alternate lowest mode location, based on lower signal detection threshold	meters
AZIMUTH	Azimuth angle of the laser beam	degrees
INCIDENTANGLE	Off-nadir incident angle of the laser beam	degrees
RANGE	Distance between the instrument and the ground	meters
COMPLEXITY	Complexity metric for the return waveform	N/A
SENSITIVITY	Sensitivity metric for the return waveform	N/A
ENERGY1	Signal return energy for channel 1	counts
ENERGY2	Signal return energy for channel 2	counts

Parameter	Description	Units
ENERGY3	Signal return energy for channel 3	counts
CHANNEL	Flag indicating LVIS channel used to extract Level-2 parameters	N/A