Global Ecosystem Dynamics Investigation (GEDI) Level 1B User Guide

For SDPS PGEVersion 3 (P003) of GEDI L1B Data

Version 1.0

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Science Team

Principal Investigator: Ralph Dubayah

Deputy Principal Investigator and Instrument Scientist: J. Bryan Blair

Deputy Principal Investigator: Scott Goetz

Co-Investigators: Matt Hansen, Sean Healey, Michelle Hofton, George Hurtt, Lola Fatoyinbo, Jim Kellner & Scott Luthcke

Research Scientists: John Armston, Patrick Burns, Laura Duncanson, Paul Patterson, Steven Hancock, Patrick Jantz, David Minor, Wenlu Qi, Hao Tang,

Graduate Assistants: Suzanne Marselis & Jamis Bruening

Project Manager: Jim Pontius

User Guide written by Jared Beck[1] in collaboration with Scott B. Luthcke, Michelle Hofton, and John Armston.

[1] KBR, Inc., contractor to the U.S. Geological Survey, Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, USA. Work performed under USGS contract G15PC00012 for LP DAAC[2].

[2] LP DAAC work performed under NASA contract NNG14HH33I.

Document History

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1 Dataset Overview

The overall goal of the Global Ecosystem Dynamics Investigation (GEDI) mission is to advance our ability to characterize the effects of changing climate and land use on ecosystem structure and dynamics. The GEDI instrument produces high-resolution laser ranging observations of the 3-dimensional structure of the Earth. GEDI is attached to the International Space Station and collects data globally between 51.6° N and 51.6° S latitudes. GEDI measurements of forest canopy height, canopy vertical structure, and surface elevation are used to characterize important carbon and water cycling processes, biodiversity, and habitat. The GEDI data also may be used in far ranging applications such as weather forecasting, forest management, snow and glacier monitoring, and digital elevation models. GEDI is led by the University of Maryland in collaboration with NASA Goddard Space Flight Center. GEDI science data algorithms and products are created by the GEDI Science Team.

This user's guide provides information about the Science Data Processing System (SDPS) PGEVersion 3 (P003) L1B geolocated waveform product. The SDPS P003 is associated with the Release 001 to the DAAC. This product is provided in HDF5 file format. The filename convention details are provided in section 2.0 of this document.

1.1 Background

The GEDI instrument consists of 3 lasers that are split and beam dithered resulting in a total of 8 beam ground transects that are spaced 600 meters apart on the Earth's surface in the cross-track direction. Each beam consists of ~25 meter (m) footprint samples approximately spaced every 60 m along track. Captured in real time by the GEDI instrument are the shapes of the transmitted and reflected laser waveforms, enabling a precise range to the reflecting surface to be calculated for every shot (after accounting for the speed of light). The laser receive waveform represents the vertical distribution of intercepted surfaces as a function of range. Over non-complex, flat terrain the laser receive waveform shape will look similar to the shape of the outgoing (transmitted) laser pulse. Over complex or sloped terrain, photons may be reflected from multiple surfaces within the footprint resulting in a receive waveform with multiple modes. Interpretation of the laser pulse in post-processing enables precise information on surface elevation, structure, and relative heights to be derived. The L1B geolocated waveform product contains precise geolocation information for the first and last sample bins of each GEDI laser return waveform. The L2 geolocated elevation and height products contain precise geolocation for each reflecting surface within the receive waveform.

For a detailed description of the satellite and reference data, processing schemes, approaches, methods, and other information, refer to the algorithm theoretical basis documents (ATBDs) for geolocation and waveform processing and the mission website.

GEDI ATBD for GEDI Waveform Geolocation for L1 and L2 Products, Luthcke et al.

GEDI ATBD for Waveform Processing for L1 and L2 Products, Hofton et al.

1.2 Important Product Notes for P003 L1B

The P003 L1B product was generated using preliminary and limited geolocation and waveform parameter calibration and validation. Data product performance, and especially geolocation performance, is expected to significantly improve in future releases as data over a wider scope of instrument operating conditions will be analyzed with considerably more comprehensive calibration and overall product validation. The L1B product contains all geolocated return waveforms. The L1B product provides corrected geolocated waveform returns, including transmit and receive housekeeping and relevant instrument parameters, as well as geolocation parameters and geophysical corrections. At the processing level of the L1B product, the waveform returns have not been filtered nor has noise characterization been conducted to determine if a valid land surface return exists.

2.0 Dataset Characteristics

Global Ecosystem Dynamics Investigation Geolocated Waveforms (GEDI_01B) collection, granule, and dataset characteristics are described below.

2.1 GEDI Geolocated Waveforms Product P003

2.1.1 Collection Level

Table 1. Collection Level Data

Characteristic	Description
Collection	GEDI
Short name	GEDI_01B
DOI	10.5067/GEDI/GEDI01_B.001
Temporal Resolution	Varies
Temporal Extent	2019-04-18 – Present
Spatial Extent	Global (51.6 °S to 51.6 °N)
Coordinate System	Geographic (lat/lon)
Datum	WGS84
Geographic Dimensions	4.2 km across-track by one full ISS orbit along-track
File size	~7GB
File Format	HDF5

2.1.2 Granule Level

Table 2. Granule Level Data

Characteristic	**Description**
Number of Science Dataset (SDS) Layers	92 per beam
Columns/Row	Variable
Pixel Size	25 m (footprint diameter)

2.1.3 Data Layer Characteristics

Please refer to the Level 1B data dictionary for a complete description of the product attributes, groups, and datasets, including datatype, dimensions, units, source, and short definition/description.

Each shot has a unique shot identifier (shot number) that is available within each data group of the product. The shot number is important to retain in any data subsetting as it will allow the user to link any shot record back to the original orbit data, and to link any shot and its data between the L1 and L2 products. The shot number has the following format:

OOOOOBBFFFNNNNNNNN

where:

OOOOO: Orbit number

BB: Beam number

FFF: Minor frame number (0-241)

NNNNNNNN: Shot number within orbit

If a data packet is dropped (never received on the ground), NNNNNNNN will not save space for it; however, if we receive a packet with a bad Cyclic Redundancy Check (CRC) error detection, it will be “skipped” in NNNNNNNN in case it can be corrected in later processing.

2.1.4 Filename Convention

GEDI filenames (i.e., the local granule ID) follow a naming convention which provides useful information regarding the specific product.

In this example of a level 01B product, the filename **GEDI01_B_2019165230622_O02859_T04183_02_003_01.h5** indicates:

- **GEDI01_B** = Product Short Name
- **2019165**= Julian Date of Acquisition in YYYYDDD

- **230622**= Hours, Minutes and Seconds of Acquisition (HHMMSS)
- **O02859**= O = Orbit, 01997 = Orbit Number
- **T04183**= T = Track, **04183**= Reference Ground Track Number
- **02** = Positioning and Pointing Determination System (PPDS) type (00 is predict, 01 rapid, 02 and higher is final.)
- **003** = PGEVersion = SDPS Release Number
- **01** = Granule Production Generation Number

2.1.5 File Format

The GEDI products are stored in Hierarchical Data Format 5 (HDF5), a self-descriptive data file format designed by the National Center for Supercomputing Applications to assist users in the storage and manipulation of scientific data across diverse operating systems and machines.

3 Algorithm Description

3.1 Geolocation Algorithm Overview

The GEDI geolocation algorithm uses the instrument pointing, position, and observed range to compute the planet referenced location of the first and last samples of each laser receive waveform.

Instrument positioning and pointing information are derived from GPS and star tracker sensors located on the instrument. During post-processing, this information is combined with the laser range and various measurement model parameters to geolocate the laser footprint. Atmospheric path delays are also accounted for at this stage. The location of the laser footprint is derived in Cartesian coordinates in an Earth Centered Inertial (ECI) or Earth Centered Fixed (ECF) reference frame and then transformed to geodetic coordinates of latitude, longitude, and height (elevation) above the reference ellipsoid, which are available in the data product.

The user is highly encouraged to refer to the "GEDI ATBD for GEDI Waveform Geolocation for L1 and L2 Products" for a complete description of the geolocation algorithm and definitions, and details of the geolocation and geophysical corrections parameters. In particular, Sections 3.1, 3.6, and 3.7 provide a more focused understanding of the L1B geolocation and geophysical correction parameter groups.

3.2 Waveform Algorithm Overview

A digitally recorded return laser pulse, or waveform, represents the time history of the laser pulse as it interacts with the reflecting surfaces. The waveform can have a simple (single-mode) shape similar to that of the outgoing pulse or be complex and multimodal with each mode representing a reflection from an apparently distinct surface within the laser footprint. Simple waveforms are typical in ocean or bare-ground regions and complex waveforms in rough terrain or vegetated regions. The first and last modes (i.e. detected signal above noise) within the waveform are associated with the highest and lowest perceived reflecting surfaces within the footprint, respectively. The geolocation to the various surface ranging points are available in the L2 products.

The Rx waveform in the L1B data is the downlinked waveform smoothed to correct for noise bias. The waveform processing algorithms used by GEDI are described in section 1.4 of the GEDI ATBD for Waveform Processing for L1 and L2 Products and are adapted from methods developed for the analysis of waveforms acquired from NASA's Land, Vegetation and Ice Sensor (LVIS) (Blair et al., 1999).

4 Metadata

GEDI products have two sources of metadata: the embedded HDF5 metadata and the external ECS metadata. The HDF metadata contains valuable information including global attributes and dataset specific attributes pertaining to the granule. The ECS (generated by the EOSDIS Core System) .met file is the external metadata file in XML format, which is delivered to the user along with the GEDI product. It provides a subset of the HDF metadata.

The Data Set attributes contain specific SDS information such as the data range and applicable scaling factors for the data. The LP DAAC data products page provides these details within a concise document for each of the products. An HDF5 file also contains core metadata essential for search services. It is difficult for a standard HDF call to interpret HDF5 geolocation or temporal information without further knowledge of the file structure.

5 Frequently Asked Questions

How do I cite the data?

The following citation information is applicable for the GEDI01_B.001 product:

Dubayah, R., Luthcke, S., J. B. Blair, Hofton, M., Armston, J., Tang, H. (2020). *GEDI L1B Geolocated Waveform Data Global Footprint Level V001* [Data set]. NASA EOSDIS

Land Processes DAAC. Accessed YYYY-MM-DD from https://doi.org/10.5067/GEDI/GEDI01_B.001.

What science datasets does the Global Ecosystem Dynamics Investigation Geolocated Waveforms product contain?

The L1B product provides corrected geolocated waveform returns, including transmit and receive housekeeping and relevant instrument parameters, as well as geolocation parameters and geophysical corrections.

The detailed product contents are defined in the GEDI L1B Product Data Dictionary.

How do I visualize the GEDI01_B waveforms?

The LP DAAC has created a tutorial to explain how to visualize the GEDI Level 01B waveforms. The tutorial can be found at the LP DAAC website under E-learning Materials(link to future tutorial).

Why is the uneven spacing between beams across track?

While the design of the instrument and its operational implementation are to provide even crosstrack spacing of the beams, several factors cause the beams to have small differences in the crosstrack spacing. These factors include slight variations in beam alignment in the instrument frame, changes in altitude of the ISS, and changes in ISS attitude orientation, specifically yaw.

6 Quality and Important Notes

The Level 1B product is intended for users who are interested in analyzing the entire return waveform themselves. Most users should start with the Level 2 data files. The Level 1B geolocated waveforms provide context and source data for the GEDI Level 2 products that will allow the expert user to replicate or derive new geolocated Level 2 data products using different algorithms and methodologies for ground and feature finding.

There are numerous time periods where the geolocation performance suffers due to non-optimal operating conditions. These situations include blinding of 1 or more instrument star trackers, or when one or more of the trackers are suffering from significant glinting. The “degrade” dataset in the “geolocation” group provides an indication of when there is degraded geolocation. The “degrade” flag is a best estimate of these time periods and data could be performing better or worse in the surrounding time periods near the start and stop of the “degrade” flagged intervals. The “degrade” flag should be understood as a general indicator of a potential issue.

The first (elevation_bin0) and last (elevation_lastbin) return in the waveform are geolocated. To compute the geolocation of any point in the waveform (e.g. ground return), the user would interpolate the first and last return geolocation to the waveform location of interest. Please note that this is done in the L2 products where the geolocation of the ground return and other waveform metrics are provided.

The L1B product geolocation group contains several “error” datasets (i.e. latitude_lastbin_error). These are formal propagated errors that have not yet been fully calibrated. Their relative magnitude is a good indicator of relative geolocation quality, but their absolute magnitudes should not be interpreted as the actual geolocation error at this time. Future releases will contain fully calibrated geolocation “error” datasets that then can be used for an estimate of absolute error.

The user is encouraged to read section 3.7 of the “ATBD for GEDI Waveform Geolocation for L1 and L2 Products” to fully understand the application of the geophysical corrections. Of special note: **The ellipsoid height of bounce points within the /geolocation group (*elevation_bin0* and *elevation_lastbin*) has been corrected for solid earth tides, ocean loading, solid earth pole tide, and ocean pole tide.** The bounce points are NOT corrected for ocean tides and dynamic atmospheric correction. These corrections are applied by subtracting the corrections from the bounce point elevations. To remove the corrections already applied (restore the geophysical signal of interest), corrections need to be added to the bounce point elevations.

For complete and updated information regarding product quality, see the GEDI Mission Website.

7 Known Issues

The geolocation was computed using limited and preliminary calibration analysis; therefore, marked improvements in geolocation are expected in future releases as data over a wider scope of instrument operating conditions will be analyzed with considerably more comprehensive calibration and overall product validation. The user should not conclude the GEDI geolocation performance from these early release data.

Through geolocation parameter calibration, independent data comparisons, and crossover analysis, the current geolocation performance is assessed to be on the order of 15 – 20 m horizontal with noise contributions on the order of 8 m 1-σ, and systematic contributions on the order of 8 to 10 m. The systematic contributions vary through time, and current analysis shows these will be largely removed through more comprehensive calibration. Analysis projects the ultimate geolocation performance will be at the 8 m horizontal level.

The range/elevation performance has been assessed through direct altimetry to known surfaces, comparisons to independent data, and crossover analysis. The fundamental instrument ranging precision is on the order of 3 cm. Current range/elevation errors are on the order of -40 cm ("negative" means the range is too long or elevation is below surface) for a long-term slow varying bias and 40 cm 1-σ from noise and time varying systematic errors. Analysis shows the overall bias will be corrected when calibrating and modeling the receive tracking point. The noise will be reduced with improvements in calibrating and modeling the time varying systematic errors.

See Section 6 of the GEDI ATBD for GEDI Waveform Geolocation for L1 and L2 Products for discussion of geolocation "error" datasets. As noted in Section 6, these errors have not been fully calibrated in the current release and should not be interpreted as an estimate of the absolute error. Future releases will contain fully calibrated geolocation "error" datasets that then may be used as an estimate of absolute error.

There is a known ranging issue affecting the absolute elevations of two of the eight beams (Beam0000 and Beam0001). This issue occurs in ~5% of the shots of these two beams and results in an overestimation of the range to the surface by ~60 cm. The precise mechanism of what is occurring is that the time tag of the return waveform is randomly incorrect by 4ns. The return waveform itself is unaffected, so the products derived from the waveform (e.g., canopy/relative height metrics) are unaffected. Users requiring absolute elevation accuracy of better than 60 cm should avoid using beam0000 and beam0001. A modification to the onboard FPGA has been completed and will be uploaded to GEDI to correct this issue.

8 Dataset Access

The GEDI_01B product is available through the LP DAAC Data Pool and NASA Earthdata Search.

9 Contact Information

LP DAAC User Services
U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center
47914 252nd Street Sioux Falls, SD 57198-0001
Phone Number: 605-594-6116
Toll Free: 866-573-3222 (866-LPE-DAAC)
Email: lpdaac@usgs.gov
Web: https://lpdaac.usgs.gov

GEDI Science Team Contact: Ralph Dubayah (PI), Professor of Geographical Sciences at the University of Maryland: dubayah@umd.edu

10 Citations

Dubayah, R., Luthcke, S., J. B. Blair, Hofton, M., Armston, J., Tang, H. (2020). *GEDI L1B Geolocated Waveform Data Global Footprint Level V001* [Data set]. NASA EOSDIS Land Processes DAAC. Accessed YYYY-MM-DD from https://doi.org/10.5067/GEDI/GEDI01_B.001.

11 Publications, References, and Resources

Blair J.B, Rabine D.L., Hofton M.A, The Laser Vegetation Imaging Sensor: a medium-altitude, digitisation-only, airborne laser altimeter for mapping vegetation and topography. *Isprs J. Photogramm. Remote Sens.* **54**, 115–122 (1999).

Dubayah, R. O., Blair, J. B., Goetz, S. J., Fatoyinbo, L., Hansen, M. C., Healey, S. P., Hofton, M., Hurtt, G., Kellner, J. R., Luthcke, S., Armston, J., Tang, H., Duncanson, L., Hancock, S., Jantz, P., Marselis, S., Patterson, P., Qi, W., Silva, C. (2020). The Global Ecosystem Dynamics Investigation: High-resolution laser ranging of the Earth's forests and topography. Science of Remote Sensing (in press).

Hofton et al. (2020). ATBD for GEDI Waveform Geolocation for L1 and L2 Products

Luthcke et al. (2020). ATBD for Waveform Processing for L1 and L2 Products

11.1 Project Website

The GEDI Mission maintains a website at https://gedi.umd.edu/.

11.2 Additional Resources

The GEDI L1B data dictionary can be found at: https://lpdaac.usgs.gov/documents/585/gedi_l1b_product_data_dictionary_P003_v1.html

NASA Goddard Space Flight Center video on "NASA's Laser Mission to Measure Trees" at: https://www.youtube.com/watch?v=qpzFn5bqhl4