GLAS/ICESat L1 and L2 Global Atmospheric Data (HDF5), Version 33

USER GUIDE

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/GLAH02 (GLAH07, GLAH08, GLAH09, GLAH10, and GLAH11)

National Snow and Ice Data Center

How to Cite These Data

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

Zwally, H. J., R. Schutz, D. Hancock, and J. Dimarzio. 2013. *GLAS/ICESat L1B Global Backscatter Data (HDF5), Version 33*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ICESAT/GLAS/DATA107. [Date Accessed].

Zwally, H. J., R. Schutz, D. Hancock, and J. Dimarzio. 2013. *GLAS/ICESat L2 Global Planetary Boundary Layer and Elevated Aerosol Layer Heights (HDF5), Version 33*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ICESAT/GLAS/DATA201. [Date Accessed].

Zwally, H. J., R. Schutz, D. Hancock, and J. Dimarzio. 2013. *GLAS/ICESat L2 Global Cloud Heights for Multi-layer Clouds (HDF5), Version 33*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ICESAT/GLAS/DATA202. [Date Accessed].

Zwally, H. J., R. Schutz, D. Hancock, and J. Dimarzio. 2013. *GLAS/ICESat L2 Global Aerosol Vertical Structure Data (HDF5), Version 33*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ICESAT/GLAS/DATA203. [Date Accessed].

Zwally, H. J., R. Schutz, D. Hancock, and J. Dimarzio. 2013. *GLAS/ICESat L2 Global Thin Cloud/Aerosol Optical Depths Data (HDF5), Version 33*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ICESAT/GLAS/DATA204. [Date Accessed].

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1 DATA DESCRIPTION

NOTE: References in this documentation to GLAS binary product names GLA01 to GLA15 refer to original GLAS binary data, and are retained here for informational and provenance purposes. Access to GLAS binary data was removed 01 August, 2017. All GLAS data are available in HDF5 format, products GLAH01 to GLAH15.

This document covers six data sets as listed in Table 1**Error! Reference source not found.**.

Table 1. GLAS Data Sets Described in this Document

Short Name	**Long Name**
GLAH02	GLAS/ICESat L1A Global Atmosphere Data (HDF5)
GLAH07	GLAS/ICESat L1B Global Backscatter Data (HDF5)
GLAH08	GLAS/ICESat L2 Global Planetary Boundary Layer & Elevated Aerosol Layer Heights (HDF5)
GLAH09	GLAS/ICESat L2 Global Cloud Heights for Multilayer Clouds (HDF5)
GLAH10	GLAS/ICESat L2 Global Aerosol Vertical Structure Data (HDF5)
GLAH11	GLAS/ICESat L2 Global Thin Cloud/Aerosol Optical Depths Data (HDF5)

Level-1A atmospheric data (GLAH02) include the normalized relative backscatter for the 532 nm and 1064 nm channels, and low-level instrument corrections such as laser energy normalization for both channels, background subtraction, range square correction, dead time correction for 532 nm, photon coincidence for 532 nm, and detector gain correction for 1064 nm.

Level-1B global backscatter data (GLAH07) are provided at full instrument resolution. The product includes full 532 nm (41.1 to -1.0 km) and 1064 nm (20 to -1 km) calibrated attenuated backscatter profiles at 5 times per second, and from 10 to -1 km, at 40 times per second for both channels. Also included are calibration coefficient values and molecular backscatter profiles at once per second. Data granules contain approximately 190 minutes (2 orbits) of data. The 532 nm data are calibrated using the molecular return from about 30 km altitude. The 1064 nm channel is not sensitive enough to measure a molecular return, and is calibrated using the instrument parameters and airborne validation measurements. The molecular backscatter cross section is computed from either standard atmospheric data (temperature and pressure as a function of height) or, when available, the NCEP gridded analysis fields of temperature and pressure interpolated to the spacecraft position and time.

The Level-2 planetary boundary layer (PBL) and elevated aerosol layer heights product (GLAH08) contains top and bottom heights of elevated aerosols from -1.5 km to 20.5 km (4 second sampling rate) for up to five layers, and up to three layers between 20.5 km to 41 km (20 second sampling rate).

The Level-2 cloud heights for multi-layer clouds products (GLAH09) contains cloud layer top and bottom height data at sampling rates of 4 seconds, 1 second, 5 Hz, and 40 Hz.

The Level-2 aerosol vertical structure product (GLAH10) contains the attenuation-corrected cloud and aerosol backscatter and extinction profiles at a 4 second sampling rate for aerosols and a 1 second rate for clouds.

The Level-2 thin cloud/aerosol optical depths product (GLAH11) contains cloud and aerosol optical depths. A thin cloud is one that does not completely attenuate the LIDAR signal return, which generally corresponds to clouds with optical depths less than about 2.0.

Each data granule has associated browse products that users can quickly view to determine the general quality of the data in the granule. Browse products consist of image plots of key parameters and statistics.

1.1 Parameters

Please see the following tables of data records for each product. Data records describe data product structure and parameters.

GLAH02 Records
GLAH07 Records
GLAH08 Records
GLAH09 Records
GLAH10 Records
GLAH11 Records

1.1.1 Parameter Description

See the GLAS Atmospheric Products User Guide (PDF, 213 KB) for details of working with the GLAS atmospheric parameters.

1.2 File Information

1.2.1 Format

GLAS HDF5 products are in Hierarchical Data Format 5 format, also known as netCDF-4/HDF5. The intent with the HDF5 format data is to make the Release 33 data available in the same format as several future NASA missions, including ICESat 2 and Soil Moisture Active Passive (SMAP), and to make ICESat 1 Release 33 data more accessible to a broader user community.

1.2.1.1 Header

The header description information found in the binary files is embedded in the HDF5 files.

1.2.1.2 Invalid values

Not all data from GLAS are suitable for science processing. Many parameters have invalid values or, in CF terms, "_FillValues". An invalid value means that the measurement is not valid for that element of data.

Each data granule has associated browse products that users can quickly view to determine the general quality of the data in the granule. Browse products consist of image plots of key parameters and statistics.

1.2.2 File Contents

Table 2 lists approximate file sizes for each product.

Table 2. Approximate File Size of Products

Product	File size
GLAH02	437 MB
GLAH07	473 MB
GLAH08	8 MB
GLAH09	50 MB
GLAH10	21 MB
GLAH11	35 MB

Total volume of the HDF5 Atmospheric data products is approximately 3 TB.

1.2.3 Naming Convention

The file naming convention is as follows:

```
GLAHxx_mmm_prkk_ccc_tttt_s_nn_ffff.h5
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Where:

Variable	Description
GLAH	Indicates GLAS HDF5 data product
xx	Product number (02, 07, 08, 09, 10, or 11)
mmm	Release number for process that created the product = 633

Variable	Description
p	Repeat ground-track phase (1 = 8-day, 2 = 91-day, 3 = transfer orbit)
r	Reference orbit number; this number starts at 1 and increments each time a new reference orbit ground track file is obtained.
kk	Instance number, incremented every time the satellite enters a different reference orbit.
ccc	Cycle of reference orbit for this phase; the cycle number restarts at 1 every time the instance number changes. The cycle number then increments within the instance (kk) every time Track 1 for that orbit is reached. Most instances begin in an arbitrary track (not 1) because of how the tracks are numbered.
tttt	Track within reference orbit; tracks are defined from a reference orbit. Each track begins and ends at the ascending equator crossing. Tracks are numbered such that Track 1 is the closest track to Greenwich Meridian from the east and then contiguous in time after that. For transfer orbits, for which we have no predefined reference orbit, Track 1 is the first track for which we have data for that instance (kk).
s	Segment of orbit
nn	Granule version number; the number of times this granule is created for a specific release
ffff	File type; numerical, assigned for multiple files as needed for data of same time period for a specific data product; a multifile granule
h5	HDF5 file

Algorithms that generate atmospheric products were continually improved as limitations became apparent in early versions of data. Release 33 is the final release of ICESat/GLAS data.

Note: Beginning with Release-28, a new convention is used for the release number (mmm) in file names.

Please see the following for more information:

ICESat/GLAS YXX Release Numbers

ICESAT/GLAS CSR SCF Release Notes for Orbit and Attitude Determination (PDF file)

1.3 Spatial Information

1.3.1 Coverage

GLAS/ICESat coverage is global between 86°N and 86°S with occasional off-nadir pointing to the poles or other targets of opportunity. GLA02 and GLA07 files span two orbits. GLA08-11 files span 14 orbits (1 day).

Spatial searching is disabled for GLA02. The orbit for GLA02 is a predicted orbit and does not show any target-of-opportunity pointing. Spatial searching for GLA02 is not enabled because of a potentially large number of false negatives. If you order GLA05 to GLA15 data granules (which support spatial searching) and you require matching GLA02 granules, please note the data times and/or file names from the GLA05 to GLA15 granules; use these times to perform your search for GLA02 granules.

1.3.2 Resolution

The atmospheric channel of GLAS measures the vertical structure of backscatter intensity (with a laser footprint of 60 m), from -1.5 km to a height of about 41 km, with 76.8 m vertical resolution. Horizontal resolution of the raw data is a function of height. Between 10.5 km and 20.5 km, eight laser shots are summed, producing a horizontal resolution of 1.4 km (5 Hz sampling rate). Between 20.5 km and 41 km, 40 shots are summed, providing a horizontal resolution of about 7.5 km (1 Hz sampling rate).

1.4 Temporal Information

1.4.1 Coverage

Please refer to the Data Release Schedule for the temporal coverage of specific products and descriptions of each release.

Also visit the official ICESat web site (follow the "Time-Track Conversion" link) to see the Pass ID for a user-specified year, day, and time.

1.4.2 Resolution

Atmospheric data are sampled 40 times per second, but not all products record data at this rate. Sampling rates include 4 seconds, 1 second, 5 Hz, or 40 Hz, depending on the product.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The ICESat GLAS Release 33 HDF5 data are converted directly from the Release 33 binary data. Data files were not re-processed during conversion. However, parameters in the HDF5 files are re-ordered, re-named, and logically grouped to take advantage of the HDF5 file structure.

Please refer to the corresponding binary product documentation (e.g. GLA02) for details on Data Acquisition Methods, Theory Of Measurements, Derivation Techniques and Algorithms, and Processing Steps.

A complete description of the physical and mathematical algorithms used in the generation of the data products can be found among the ICESat/GLAS Technical References.

2.2 Derivation Techniques and Algorithms

2.2.1 Error Sources

GLAS atmospheric data are prone to the following errors:

2.2.1.1 Normalized LIDAR signal

- Limited knowledge of the laser energy and performance
- Inaccurate dead time (photon coincidence) correction factors for the 532 nm channel, and digital-to-analog conversion factors for the 1064 nm channel
- Boresight inaccuracy
- How well the etalon filter is tuned to the laser frequency (532 nm channel)

2.2.1.2 Attenuated backscatter

- Presence of aerosol or clouds in the portion of the atmosphere used to calculate the calibration constant
- Error involved with computing the molecular backscatter cross section at the calibration height (errors in knowledge of atmospheric temperature and pressure)

2.2.1.3 Cloud layer height and Earth surface height

- Multiple scattering may cause the cloud bottom to appear somewhat lower than it actually is
- Low signal-to-noise ratio may cause false positives

2.2.1.4 PBL and elevated aerosol layer height

- Low signal-to-noise ratio may cause false positives
- Accuracy of satellite altitude and time of laser fire in the absence of a detectable ground return
- Sampling frequency (bandwidth, which determines the vertical resolution of the data)
- Number of LIDAR shots averaged together (horizontal resolution)
- Optical depth of the PBL

2.2.1.5 Optical depth

- Error in optical depth increases with layers of decreasing geometrical depth

Note that Level-0 data from 19 November to 14 December 2003 have a time stamp error, where dates are reset to 01 January 2000. This passes through to all higher-level products.

2.3 Quality, Errors, and Limitations

Browse products contain quality information. These browse products are available along with corresponding data granules.

2.3.1 Normalized LIDAR signal

The most practical way to measure data quality is to integrate the entire LIDAR signal from 20 km to the end of the profile and compute the mean signal and standard deviation. Both should fall within known limits if the data are good. A histogram of the LIDAR return is also constructed. The degree to which the histogram deviates from a Poisson distribution indicates how much of the signal is contained in the return. The "i_g_TxNrg_qf" quality flag is set for each 40 Hz shot to characterize the laser energy:

1 = full laser energy (within 90% of expected maximum value)

2 = marginal laser energy (between 70-90% of expected maximum value)

3 = deficient laser energy (less than 70% of expected maximum value)

Boresight accuracy is assessed by integrating the 532 nm return signal from 20 km to 41 km. The expected number of integrated photons (Is) in this region is about 800. A quality flag is set, depending on the magnitude of the integrated return:

1 = excellent signal strength (Is > 800)

2 = good signal strength (600 < Is < 800)

3 = marginal signal strength (400 < Is < 600)

4 = poor signal strength (200 < Is < 400)

5 = bad data (Is < 200)

2.3.2 Attenuated backscatter

Confidence flags include a measure of the variability of the calibration constant (for both channels) as a function of time, and the quality of the attenuated backscatter profile. The laser energy flag and the integrated return flag should be evaluated to eliminate bad shots. Quality of the calibration constant is assessed by evaluating its variability with time and the difference between the constants calculated at two different heights. The 532 nm attenuated backscatter cross-section profiles are checked by normalizing them by the attenuated molecular profile. This should produce a profile that ranges between 0.9 and about 10.0. This test could only be applied to data with a ground return, as the values below thick clouds will approach zero. Another test is to integrate the attenuated backscatter from 20 km to 40 km and divide by the integrated attenuated molecular backscatter to form a ratio very close to unity. A major deviation from "1" would indicate a problem (Palm et al. 2002).

2.3.3 Cloud layer height and Earth surface height

Quality of this product is judged by how successful it is at finding all detectable cloud layers and locating their boundaries in the atmospheric profile. The best approach is to plot the computed cloud boundaries on top of image segments constructed from LIDAR profiles. These should reveal systematic and random faults in the results of the procedure. If shortcomings exist, parameters used in the computation of thresholds will be adjusted to fix the discrepancies.

The following confidence tests are used for the layer boundary results of each profile:

- For each layer detected, a flag to indicate high, medium, or low confidence
- For the top and bottom of each layer, a single number indicating a number of sample bins within which the boundary exists at a specified probability
- For each profile, a single number representing the probability that an undetected layer exists
- For a positive ground signal, a flag to indicate a high, medium, or low confidence
- For a positive ground signal, the number of sample bins within which the actual ground height exists at a specified probability
- For negative ground signal detection, a probability that a detectable ground signal actually exists but the algorithm fails to calculate a ground signal

2.3.4 PBL and elevated aerosol layer height

Confidence of height determination is measured by the difference between the average signal levels outside and inside of the PBL. Confidence is also measured by the standard deviation of the heights for a given segment.

2.3.5 Optical depth

- Layers will be screened so they don't overlap or become embedded.
- Visual screening with imagery will occur to ensure layers are labeled "cloud" or "aerosol" or "polar stratospheric cloud" correctly.
- As transmission profiles are processed, transmission calculations will be tested for out-of-bounds situations such as increasing transmission with range or large negative transmission.
- Confidence flags will be produced for each particulate layer or profile to determine the number and type of suspect input parameters, and whether the transmission profiles passed their tests. This information will be passed to each of the output parameter confidence flags.

2.4 Instrumentation

2.4.1 Description

The Geoscience Laser Altimeter System (GLAS) instrument on the Ice, Cloud, and land Elevation Satellite (ICESat) provides global measurements of polar ice sheet elevation to discern changes in ice volume (mass balance) over time. Secondary objectives of GLAS are to measure sea ice roughness and thickness, cloud and atmospheric properties, land topography, vegetation canopy heights, ocean surface topography, and surface reflectivity.

GLAS has a 1064 nm laser channel for surface altimetry and dense cloud heights, and a 532 nm LIDAR channel for the vertical distribution of clouds and aerosols.

Please refer to the official ICESat/GLAS Web site at NASA GSFC for details of the ICESat platform and GLAS instrument.

Also see ICESat Reference Orbit Ground Tracks for a summary of the orbits for each laser operational period.

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.

HDF Explorer: Data visualization program that reads Hierarchical Data Format files (HDF, HDF-EOS and HDF5) and also netCDF data files.

Panoply netCDF, HDF and GRIB Data Viewer: Cross-platform application. Plots geo-gridded arrays from netCDF, HDF and GRIB datasets.

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

For tools related to the original binary GLAS data, see the ICESat/GLAS web page at NSIDC.

4 REFERENCES AND RELATED PUBLICATIONS

Please refer to the Published Research page.

4.1 Related Data Collections

Ice sheet altimetry data sources include:

Shuttle Laser Altimetry data

See also:

GLAS/ICESat L1A Global Engineering Data (HDF5)

GLAS/ICESat L1A Global Laser Pointing Data (HDF5)

4.2 Related Websites

NASA ICESat & ICESat-2

NASA Operation IceBridge

NSIDC DAAC IceBridge Data

NSIDC DAAC ICESat-2

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Publication Date

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6.2 Date Last Updated

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