GLAS Atmospheric HDF5 Products User Guide
July, 2012

General

The final GLAS data products (rel33) exist in two formats; the original binary format and HDF5 (Hierarchical Data Format). The HDF5 products were created from the binary products as one for one data products with the integer parameters scaled to algorithm units. In effect the HDF5 parameters should be the same as those on the binary products. A few added value features were implemented on the HDF5 products like full UTC time for each shot instead of delta times.

The binary products were produced during the full operations years of the ICESat mission with the final version produced after GLAS took its last data. This user guide was modified from the binary product user guide to cover the usage of the HDF5 products but the guides are conceptually the same. There are two basic differences that apply to the HDF5 guide. First the parameters on the binary are in scaled integers but the parameters on the HDF5 are in converted science units that mostly are real valves. The binary guide uses "i_*name*" for the parameters (see the GLAS binary data dictionary) where the HDF5 will be the same parameter but generally appears as "r_*name*" (see the GLAS HDF5 data dictionary). The second difference is that the packed flags on the binary were made individual parameters. The HDF5 data dictionary provides the names of the unpacked flags and their descriptions.

The GLAS atmospheric measurements utilize a dual wavelength (532 and 1064 nm) transmitting laser to obtain backscattering information on clouds and aerosols at varying time resolutions. The fundamental frequency of the laser and backscatter measurements is 40 Hz, but most of the derived parameters require some averaging to increase signal to noise. This can be as long as 20 seconds for stratospheric aerosol layers. The GLAS atmospheric products consist of the level 1A GLAH02, level 1B GLAH07 and level 2 GLAH08-11 data products. These products are listed below.

- **GLAH02**: Level-1A atmospheric data include the normalized relative backscatter for the 532 nm and 1064 nm channels where low-level instrument corrections such as laser energy (1064 nm and 532 nm), range, photon coincidence (532 nm), and detector gain correction (1064 nm) have been made, but the data are not calibrated. Also included are many instrument and engineering parameters.
- **GLAH07**: Level-1B global backscatter data are provided at full instrument resolution. The product includes full 532 nm (40.5 to -1.5 km) and 1064 nm (20 to -1.5 km) calibrated attenuated backscatter profiles at 5 times per second, and from 10 km to -1.5 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.
- **GLAH08**: Level-2 planetary boundary layer (PBL) and elevated aerosol layer heights. These data contain PBL heights at 0.25 Hz and 5 Hz ground detection heights, and top and bottom heights of elevated aerosols from -1.5 km to 20.5 km (4 second sampling rate), and from 20.5 km to 40.5 km (20 second sampling rate).

- **GLAH09**: Level-2 cloud heights for multi-layer clouds (up to 10 layers) contain cloud layer top and bottom height data at sampling rates of 0.25 Hz, 1 Hz, 5 Hz, and 40 Hz (for clouds below 10 km). Also separately provided are cloud layer heights obtained from the 1064 channel data at 0.25 Hz and 1 Hz sampling interval, and blowing snow over the polar regions.
- **GLAH10**: Level-2 aerosol vertical structure data contain the attenuation-corrected cloud and aerosol backscatter and extinction profiles at a 0.25 Hz sampling rate for aerosols and a 1 Hz rate for clouds.
- **GLAH11**: Level-2 thin cloud/aerosol optical depths data contain thin cloud and aerosol optical depths as derived from the 532 channel. 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 3.0. Also provided is the column optical depth over oceans from the 1064 channel.

GLAS experienced a number of problems that either eliminated or severely reduced the amount and quality of atmospheric data that was obtained. This is especially true for the 532 channel, which was not operating at all for the laser 1 observation period and provided optimal data only during the laser 2A and early 2B periods (see Table 1). For most of the other operations periods, the 532 data are unusable during the daytime but contain useful information in the nighttime portion of the orbits. As will be seen later in this document, many of the atmospheric parameters that are retrieved from GLAS use the 532 nm channel data. When the 532 laser energy drops below about 5 mJ, the signal to noise ratio is not sufficient to perform many of the retrievals during the daytime. The atmospheric parameters derived from the 1064 channel, while not as extensive as the 532 channel, are less affected by laser problems until laser energy dropped below about 30 mJ, during the laser 3F operating period. The main effect of low laser energy is to decrease the signal to noise ratio of the data, which first affects the daytime measurements but will eventually compromise the nighttime data as well.

Table 1. GLAS Operating Periods and Data Quality

Operating Period	Dates	Data Quality 532	Data Quality 1064	Average Laser Energy 1064/532
L1	20Feb03 - 29Mar03	None	Excellent	65/NA
L2A	25Sep03 - 18Nov03	Excellent	Excellent	70/20
L2B	17Feb04 - 21Mar04	Excellent - Fair	Excellent - Good	45/8
L2C	18May04 - 21Jun04	Poor	Poor	15/2
L3A	04Oct04 - 09Nov04	Fair - Poor	Excellent	65/5
L3B	17Feb05 - 24Mar05	Fair - Poor	Excellent	60/4
L3C	20May05 - 24Jun05	Fair - Poor	Excellent	50/3
L3D	21Oct05 - 24Nov05	Fair - Poor	Excellent - Good	40/2
L3E	22Feb06 - 28Mar06	Fair - Poor	Good - Fair	35/1.5
L3F	24May06 - 26Jun06	Poor	Fair	30/1.3
L3G	25Oct06 – 27Nov06	Poor	Poor	26/1.1
L3H	12Mar07 – 14Apr07	Poor	Poor	22/1.0
L3I	02Oct07 – 05Nov07	Poor	Poor	20/0.9

L3J	17Feb08 – 21Mar08	None	Poor	18/0.8
L3K	06Oct08 – 19Oct08	None	Very Poor	05/0.5
L2D	24Nov08-17Dec08	Poor	None	04/0.6

The discussions presented below on the GLAS atmospheric data products are not meant to provide a complete listing of all the parameters available in each, but rather give the user a general overview of the main parameters in each product and sometimes a brief description of how they were derived. For more in-depth information on the contents of the products, the user is directed to the GLAS HDF5 Atmosphere Data Dictionary which gives a full listing of all parameters and also the grouping of the data product files. To obtain more information on how the parameters are derived from the raw GLAS backscatter data, the user can reference the GLAS Atmospheric Data Products Algorithm Theoretical Basis Document (ATBD) available at ******* NSIDC should make this a link they keep******* http://www.csr.utexas.edu/GLAS/atbd.html. In addition, the user is encouraged to visit the GLAS Atmospheric Data Product web pages at *******NSIDC this link does work but NSIDC can decide if the sentence should be deleted****** http://glo.gsfc.nasa.gov. There the user can find quick look images of atmospheric data acquired for all of the GLAS data operation periods and displays of various parameters contained in the GLAS atmospheric data products (GLAH07-11). Since GLAH02 contains raw uncalibrated data and consists mainly of engineering and system related parameters, it is not included in the users guide at this time.

Expected minimum and maximum values are provided for parameters but values are not forced to these limits. Flags and invalid values should be used to determine the validity of parameters.

GLAH07 – Attenuated, Calibrated Backscatter

GLAH07 contains the calibrated, attenuated backscatter for both the 1064 nm and 532 nm channels at 5 Hz and 40 Hz resolutions. Backscatter units are in m^{-1} sr^{-1}, where "sr" is steradian, the International System of Units (SI) unit of solid angular measure. The 5 Hz 532 channel profiles (GLAH07 product variable r5_g_bscs) begin at roughly 40.5 km (bin 1) above the ellipsoid (nearly equivalent to mean sea level) and end about 1.5 km below the ellipsoid (bin 548). The 5 Hz 1064 channel profiles (r5_ir_bscs) begin at 20.5 km (bin 1) and end at 1.5 km below the ellipsoid (bin 280). The 40 Hz profiles for both 532 (r40_g_bscs) and 1064 (_ir_bscs) begin at 10 km (bin 1) altitude and end at -1.5 km. The GLAS instrument's fundamental data collection frequency is 40 Hz, but the data above 20.5 km are summed to 1 second onboard the satellite before being downlinked. Eight shots are summed in the altitude region 10 to 20,5 km before being downlinked and every shot is collected below 10 km. As a result, for the 532 nm 5 Hz profiles, the data above 20.5 km are repeated five times. In other words, that portion of the profile does not change within a given second, since the data resolution is 1 Hz above 20.5 km. The vertical bin size, or resolution, is 76.8 m for all data.

GLAH07 also contains the molecular (Rayleigh) backscatter profiles for the 532 channel (r_g_mbscs) and 1064 channel (r_ir_mbscs) at 1 second resolution. The "i_metFlg" flag in GLAH07 gives the source of the meteorological data used to compute the molecular backscatter profiles (which are a function of temperature and pressure). These are usually computed from NCEP analysis fields interpolated in time and space to the spacecraft latitude and longitude. However, if for some reason the NCEP data were not available, the standard atmosphere (mid latitude, polar and tropics for summer and winter) are used based on the latitude, and time of year of the observation. All profiles have the same vertical resolution of 76.8 meters per bin.

Also included in the GLAH07 data product are the solar background measurements at 1, 5 and 40 Hz resolutions for the 532 channel (r1_g_bg, r5_g_bg and i30_g_bg) and 5 and 40 Hz for the 1064 channel (r5_ir_bg and r40_ir_bg). The 532 background given in units of photons per bin is an accurate measurement of the 532 nm solar background, but the 1064 value does not represent the true background because the 1064 detector is AC coupled which means that the background is electronically subtracted from the 1064 measurement before the data are down linked.

Here we mention only a few of the quality flags which can help the user identify good data. The 532 and 1064 nm Laser Transmit Energy Quality Flags (i_g_TxNrg_qf and i_ir_TxNrg_qf), respectively, can be used to determine the overall expected quality of the backscatter profiles as shown in Table 2. Also, the “Lidar frame quality flag” (i_LidarQF) will indicate whether the 532 nm level 2 processing (GLAH08-11) was performed. If the Lidar frame quality flag has a value of 0, then the 532 laser energy was sufficient for the level 2 processing. If this flag is 1, it means that the 532 processing occurred only for nighttime data because the laser energy has fallen below 5.5 mJ. If the 532 laser energy falls below 1.5 mJ, then the 532 level 2 processing is halted for both day and night. The value of the flag in this case remains 1 for all data (as opposed to switching from 1 to 0 when the spacecraft enters darkness and from 0 to 1 when the GLAS enters daylight as it does when the laser energy is less than 5.5 mJ but greater than 1.5 mJ). The “Lidar frame quality flag” parameter is on all of the level 2 atmospheric products. Note that this flag does not give any information about the status of the 1064 channel. For 1064 laser energy status use the i_ir_TxNrg_qf parameter.

Table 2. 532 and 1064 nm Laser Transmit Energy Quality Flag Meaning

Quality Flag	Data Quality	532 Energy	1064 Energy
0	Excellent	E >= 24.0	E >= 60.0
1	Good	24.0 > E > 14.0	60.0 > E > 36.5
2	Fair	14.0 > E > 4.0	36.5 > E > 25.0
3	Poor	E <= 4.0	E <= 25.0

The calibration of the 532 nm backscatter is performed on a continual basis using 5 minute averages of the lidar data and computed molecular backscatter between 22 and 26 km altitude. This provides a series of points along the orbit and the calibration value is linearly interpolated between them at a 1 second resolution. The 532 calibration is extremely good for night data, but during the daytime under bright background conditions, the calibration can sometimes be in error by as much as 20-30%. This is particularly a problem at the transition from night to day or less frequently day to night. When the background is somewhat lower and less varying, the daytime calibration can be quite good, though generally speaking, not as good as night. The 1064 calibration was determined by a combination of under flights with the Cloud Physics Lidar (CPL) on the NASA ER-2 and a technique which uses the ratio of the normalized 1064 return signal to the calibrated 532 attenuated backscatter from cirrus clouds. The CPL has a very well calibrated 1064 channel and was able to obtain coincident (with GLAS) measurements of clouds and aerosols which were then used as a calibration standard. It was found that the 1064 calibration did not change with time for the laser 1 and laser 3 observation periods, but did change considerably during the laser 2A period where temperature changes to the optical bench and laser were made in an effort to correct boresite misalignment. The calibration product variable names are "r_g_cal_cof" and "r_ir_cal_cof," respectively, for the 532 nm and 1064 nm channels. The 532 nm calibration is a three-word array where the first word is the calibration constant calculated from about 24 to 28 km altitude. The second word contains the calibration constant calculated from an altitude of about 10 km. The third word contains the value used to compute the calibrated backscatter. The 1064 nm calibration constant is a two-word array where the first word contains the calculated atmospheric calibration at about the 10 km height (this is never used for the actual data calibration since it is unreliable). The second word is the value used to compute the calibrated backscatter.

The saturation profiles from the 532 nm channel correspond bin-for-bin to the 40 Hz and 5 Hz atmospheric profiles described above. The saturation profiles are binary flags that indicate the associated 532 nm bin is saturated (1 = "saturation"). The 532 nm channel saturates at a level of about 8 to 10 photons per detector. This occurs mainly from dense water clouds and sometimes from the ground return. The 532 nm saturation profiles are on GLAH07. See the product format description for more information. Generally, saturation is not too much of a problem with the 532 data, but when it does occur, the calculated backscatter is likely less than it actually should be.

Note that the 532 nm lidar profiles in the GLAS HDF5 Altimetry Data Dictionary are labeled "532 nm merged attenuated backscatter." Whenever the 532 nm channel is saturated, the values can be replaced with a measurement of the cross section from the 1064 nm channel, which is not saturated; hence, the label "merged attenuated backscatter." Any such replacement is controlled by the "i_532AttBS_Flag" in the processing software. It turned out that this option was not used in practice and the 532 bins that were saturated were not replaced by 1064 data. The 1064 channel did not generally suffer from saturation, though it can occur. The maximum backscatter that the 1064 channel can measure is about 5.0×10^{-4} $m^{-1}sr^{-1}$.

GLAH08 – PBL and elevated aerosol layer heights

The level 2 GLAH08 data product contains the height of the Planetary Boundary Layer (PBL) and the top and bottom height of elevated aerosol layers (layers whose bottom is above the ground or PBL). The PBL detection algorithm uses the 532 channel data and searches from the ground upwards for the first gradient of backscatter up to an altitude of 6.5 km (above the local ground surface. Over ocean, the maximum search height to obtain the PBL top is limited to 3.5 km). When a gradient of sufficient magnitude is found, the height of the central position of the gradient is then the PBL top. By definition, the PBL bottom is the ground. The PBL top is reported at 2 horizontal resolutions – 4 seconds and 5 Hz (GLAH08 product variables r_LRpbl_ht and r_HRpbl_h, respectively). If a PBL top is found at the 4 second resolution, then 20 5 Hz profiles are then formed from the 4 seconds of data and each are searched in the same manner for PBL top. Each PBL top retrieval is given a confidence rating similar to the elevated aerosol layer flag (see below). The values run from "1" (lowest) to "13" (highest) confidence of a good PBL height retrieval. The PBL quality flag is computed from the ratio of the average signal (attenuated, calibrated backscatter) within the PBL to the average signal 500 m above the PBL. Normally, the backscatter increases significantly at the top of the PBL (compared to that above) and remains higher within the PBL unless it is attenuated by a cloud, extremely dense dust, or smoke; thus, the quality flag is proportional to the magnitude of the gradient of scattering at the PBL top. The larger this gradient, the easier it is to find the PBL top and hence the higher confidence in its detection. See the "i_LayHgt_Flag" description for more information.

One caveat to the identification of the PBL by this method is that the boundary layer at night over land collapses down to form the nocturnal boundary layer, usually 100 m or less in thickness. GLAS cannot pick this up, so over land at night if the boundary layer retrieval algorithm sees anything, it is certain to be the residual daytime boundary layer from the day before. Maritime boundary layers do not normally form a nocturnal layer and the GLAS PBL heights for marine boundary layers are good both day and night.

The elevated aerosol layers (as derived from the 532 channel) are grouped as tropospheric (below 20 km altitude) and stratospheric (above 20 km altitude) and reported as separate parameters on the product. The stratospheric (GLAH08 parameters i20_aer_top and i20_aer_bot) and tropospheric (i4_aer_top and i4_aer_bot) layers have a resolution of 20 seconds and 4 seconds, respectively. The layer height flag values ("i_LayHgt_Flag) contain the number, quality, and type of layers found. The type is either "normal" aerosol or polar stratospheric cloud (PSC). The PSC flag is set only when the layer meets certain requirements for its average temperature, latitude, and height.

The quality flags ("i20_aer_qf" and "i4_aer_qf") assign a layer quality based on the ratio of the average signal *within* the layer, divided by the average *above* the layer. Values of "1" or "2" indicate a very tenuous layer with a higher chance of being a false positive. The maximum value for this flag is 13, which indicates a layer that contains very strong backscatter and is not likely to be a false positive.

For each layer top and bottom detected (including the PBL top), the atmospheric temperature, pressure and relative humidity at that height is also reported. In addition the surface wind, temperature and specific humidity are included. These meteorological parameters come from the National Center for Environmental Prediction (NCEP) analysis. Recently added (version 29) to the GLAH08 data product is aerosol layers detected from the 1064 channel at 4 second resolution (r_Aer_ir_top and r_Aer_ir_bot). The sensitivity of the 1064 channel is considerably less than the 532 channel and will only detect the thicker elevated aerosol layers and more frequently the PBL aerosol. Note that when the 532 laser energy falls to the point where the 532 level 2 processing is halted, the 1064-based parameters (aerosol layer height in this case, but also cloud height, blowing snow and total column optical depth) are still present.

GLAH09 – Cloud Layer Heights

The level 2 GLAH09 product contains the cloud heights as detected from the 532 channel and from the 1064 channel. A maximum of 10 layers are stored on the product. These are broke into parameters for layers below 20 km and above 20 km. The cloud detection for both channels uses a basic threshold detection algorithm to locate areas of elevated signal strength that are consistent with cloud returns. The algorithm produces 532 nm cloud heights at 4 second, 1 Hz, 5 Hz and 40 Hz resolution (GLAH09 parameters r_LRcld_top and bot, r_MRcld_top and bot, r_HRcld_top and bot, and r_FRcld_top and bot). It first averages 4 seconds of data (to reduce noise) and then locates up to 10 layers within the profile, searching from highest altitude to lowest. A layer is found when 2 consecutive bins exceed the threshold and the cloud top height is assigned the height of the first of these bins. Once inside the cloud, the search for cloud bottom continues downward and the bottom is defined as that bin where the first of 2 consecutive bins drops below the threshold value. The entire profile is searched in this manner until the ground is reached or until a maximum of 10 layers have been found. If a bottom is not found before the ground is reached (as defined by the local value of the DEM) the height of the cloud bottom is set to 90 m. The algorithm then examines 4 one second average profiles, but now restricting the search to those altitude regions where layers were found from the 4 second average profile. If layers are found within the 1 second average profiles, then the 5 Hz profiles that make up the 1 second average are examined. Thus, the 4 second, 1 second and 5 Hz resolution cloud heights are “nested” in that the higher resolution searches are not performed unless a cloud was found in a lower resolution search. As stated, when the higher resolution searches are performed, they are constrained to examine the profile in the region (plus and minus 2 km) where the cloud was found in the lower resolution search. The 40 Hz search is performed independently of the other resolution searches and operates on a “per shot” basis. Also, the clouds detected from the 40 Hz search are limited to below 10 km, as GLAS acquires 40 Hz data only below 10 km. At each resolution, a cloud layer flag indicates the number of layers detected, quality and whether or not the detected layer could have been detected in the daytime. The latter flag, called the “diurnal flag” is designed to address the fact that the 532 channel has significantly less sensitivity day versus night. The diurnal flag indicates whether or not a given cloud layer detected from the 532 channel during nighttime would have been detected in “average” daylight conditions. These flags are "i_LRCL_Flag," "i_MRCL_Flag," "i_HRCL_Flag," and "i_FRCL_Flag.". Where the 4 flags are low resolution (4 second), medium resolution (1 second), high resolution 5 Hz) and full resolution (40 Hz), respectively.

The 1064 cloud height algorithm is similar to the 532 algorithm, but does not perform the search at 5 Hz. The clouds detected from the 1064 channel are reported at 4 and 1 second resolution and 40 Hz resolution (GLAH09 parameters r_LRir_cld_top and bot, r_MRir_cld_top and bot and r_FRir_cldtop and cldbot). Since the 532 nm channel is more sensitive than the 1064 nm channel, it will detect optically thin layers, as a result some layers that were detected in 532 nm go undetected in the 1064 nm channel. This is especially true for nighttime data. During daytime, the signal to noise of the two channels is more comparable, resulting in similar cloud detection ability for the two channels (this applies only for when the 532 laser energy is greater than about 10 mJ). Also on GLAH09 are the temperature, pressure and relative humidity at the height of cloud top and bottom for all resolutions of cloud detection.

The GLAH09 product contains blowing snow detection at 5 Hz resolution. This consists of 4 parameters: the height of the blowing snow layer (r_blow_snow_ht), the optical depth of the layer (r_blow_snow_od), the altimetry range delay introduced by the blowing snow layer (r_blow_snow_erd) and a blowing snow confidence flag (i_blow_snow_conf). The detection of blowing snow is important to the altimetry over ice sheets since low layers such as blowing snow can produce a large range delay (due to multiple scattering). The blowing snow detection algorithm uses the 532 channel when available (when the “Lidar frame quality flag” discussed above is 0) and switches to the 1064 channel if 532 data are not good. Note that when the 532 laser energy falls to the point where the 532 level 2 processing is halted, the 1064-based parameters (cloud layer height and blowing snow in this case) are still present.

The atmosphere characterization flag (i_atm_char_flag) is new to release 33. It is part of the GLAH09 product and is intended to characterize the atmosphere to help aid in the interpretation of altimetry data. The definition and meaning of the new flag is:

0 - clear

1 - high cloud (> 5 km) low optical depth

2 - high cloud (> 5 km), high optical depth

3 - mid cloud (>2, <=5 km) low optical depth

4 - mid cloud (>2, <=5 km) high optical depth

5 - low cloud (> 500 m, <=2 km), low optical depth

6 - low cloud (> 500 m, <=2 km), high optical depth

7 - blowing snow or fog (< 500 m), low optical depth

8 - blowing snow or fog (< 500 m), high optical depth

9 - not tested

10 - data quality insufficient to assign flag

The flag is computed using the 1064 channel data since the 532 channel only operated sufficiently well for L2A and the first half of L2B. The 1064 channel, however, had sufficient laser energy to give reliable results for L1, L2A, L2B and L3A to L3I. With regard to the atmosphere's effect on range precision, the largest effect (range delay) is caused by fog or blowing snow of high optical depth (flag value of 8) followed by low clouds of high optical depth (6).

GLAH10 - Attenuated corrected backscatter and aerosol vertical structure

GLAH10 contains the optical inversion results from 532 nm backscatter and extinction cross sections, separated into cloud and aerosol components. During the daytime, the extinction profile is computed only within the cloud and aerosol layers that were detected and reported in GLAH08 and GLAH09. However, for nighttime data, in addition to the extinction being computed within the detected layers, it is also computed starting at 20 km altitude and extending down to the top of the first detected cloud layer or the top of the PBL, whichever is highest. This is new to version 29 and is known as the “free troposphere extinction retrieval”. This was implemented to pick up thin aerosol layers that were not detected by the layer search algorithm. This approach to extinction retrieval cannot be reliably used during the daytime due to problems with calibration during the day. GLAH10 also contains top and bottom heights of all the layers that were processed by the optical inversion routine. These are the same heights detected by the 532 nm channel that were reported in GLAH08 and GLAH09. Cloud products such as backscatter (r_cld1_bs), extinction (r_cld1_ext), extinction-to-backscatter ratio (r_cld1_sval)), and cloud layer tops (r_cld1_top) and bottoms (r_cld1_bot), are reported at a 1 sec sampling rate, while aerosol extinction (r_aer4_bs_prof) and attenuation corrected backscatter (r_aer4_ext_prof) are reported at a 4 sec rate only. Polar stratospheric clouds (PSC) are part of the aerosol category.

To obtain the complete vertical optical structure, you should merge the aerosol and cloud components. For every atmospheric layer detected by 532 nm, an extinction-to-backscatter ratio (S) value is calculated or estimated, which reflects the current multiple scattering condition. This calculation is essential to complete the optical inversion. "True S" indicates conditions with no multiple scattering. The Aerosol True S Values flag ("i_aer4_sval1") refers to whether the calculated (flag = 2) or estimated (flag = 1) S value was used in the optical inversion process.

The "ground detection" parameter (r_cld1_grd_det) refers to the height where the lidar sensed the ground. If the ground was not sensed, this parameter is set to "invalid." This parameter is useful for determining whether the last layer bottom sensed was a true bottom or if it marks the time when lidar signal was extinguished. The “free troposphere bottom height” parameter (r_aod_botht_4s) refers to the bottom height of the cloud-free upper troposphere above any PBL. This height marks the top of the highest cloud or the top of the PBL, whichever is highest and is the bottom height of the free tropospheric extinction retrieval mentioned above. All layer locations and heights are referenced from the geoid, and all extinction profiles are corrected for multiple scattering. The multiple scattering correction factor is not stored in GLAH10, but rather in GLAH11. Each GLAH10 record is 4 sec long and contains one group of aerosol products and four groups of cloud products (one for each second). The time stamp refers to the J2000 time of the first shot of the record. J2000 time refers to the number of seconds since 01 January 2000 at 12:00 UTC.

Cloud cross-section data from the 532 nm channel are stored as 1 sec average profiles from 20.4 km (bin 1) to -1 km (bin 280) above the geoid. The 532 nm channel aerosol cross section data are stored as 4 sec average profiles from 41.0 km (bin 1) to -1.0 km (bin 548). Each vertical bin is 76.8 meters thick. The extinction-to-backscatter ratio (S) values are recorded one value per layer. There are up to 10 cloud layers in each cloud profile (obtained from the 1 sec cloud layers detected by GLAH09 using the 532 channel) and up to 9 aerosol layers in each aerosol profile (obtained from the 4 sec aerosol layers detected by GLAH08 using the 532 channel). These are broke into parameters for layers below 20 km and above 20 km. The optically processed layers are not necessarily packed toward the front of the array sequence. For aerosols, the top three layer positions are reserved for layers above 20.5 km and the last (ninth) position is reserved for the PBL. Since there are few layers detected above 20.5 km, this means the bulk of the layers (those detected in the troposphere) will begin at array position number 4. As with the other products, the atmospheric temperature, pressure and relative humidity at the various layer heights are stored on GLAH10.

All the backscatter and extinction profiles have an associated composite flag variable (i_aer4_bs_flag and i_aer4_ ext _flag) that represents conditions in each layer that makes up the profile. The composite flag is made up of two main components: the layer quality flag and layer usage flag. In all cases, the quality flag is a categorized value of the percent error calculation. For backscatter cross section, the usage flag gives saturation status. For extinction cross section, the usage flag designates layer type category.

In the GLAS HDF5 Atmosphere Data Dictionary *******NSIDC add link to their posting****** the variable "pe/bin" represents photo electrons per bin.

GLAH11 - Cloud and aerosol optical depths

GLAH11 contains the layer-by-layer optical depth retrievals from the GLAS 532 nm atmospheric profiles for clouds (r_cld1_od) and aerosols (r_aer4_od). The PBL optical depth is stored separately in the variable r_pbl4_od. Polar stratospheric clouds are part of the aerosol category. The multiple scattering correction applied to the cloud (r_cld1_msf) and aerosol (r_aer4_msf) retrievals are stored in the product. To obtain the total column optical depth, you should add the aerosol and cloud components. For every atmospheric layer detected by 532 nm, a multiple scattering flag reflects the current multiple scattering condition. Another useful parameter is the "total column aerosol optical depth" (r_aod_4s) and its associated use flag. This parameter adds the 532 nm optical depth in the free troposphere above any cloud layer (the free troposphere extinction retrieval method in the GLAH10 description) to the aerosol layer optical depths in the column, including the PBL. The use flag (i_aod_flg_4s) is indexed based on how the parameter was calculated, relating to overall quality of the result.

GLAH11 contains top and bottom heights of all the layers that were optically processed, separated into cloud (r_cld1_top and bot) and aerosol (r_aer4_top and bot). All cloud products, including optical depth, multiple scattering factor, and layer tops and bottoms, are reported at a 1 sec sampling rate. These are the same layers as reported in GLAH09. The aerosol products (for the same layers reported on GLAH08), are reported at a 4 sec sampling rate.

The "ground detection" parameter (r_cld1_grd_det) refers to the height where the lidar sensed the ground. If the ground was not sensed, this parameter is set to "invalid." This parameter is useful for determining whether the last layer bottom sensed was a true bottom or if it marks the height at which the lidar signal was extinguished. All layer locations are referenced from the geoid, and all extinction profiles were corrected for multiple scattering. The multiple scattering correction factor (r_cld1_msf) used to correct the cloud backscatter for the effects of multiple scattering is stored in GLAH11. There is also one for the aerosol backscatter (r_aer4_msf). Each GLAH11 record is 4 sec long and contains one group of aerosol products and four groups of cloud products (one for each second). The time stamp refers to the J2000 time of the first shot of the record. J2000 time refers to the number of seconds since 01 January 2000 at 12:00 UTC.

The 532 nm cloud layer data are stored as 1 sec average values, and the 532 nm aerosol layer data are stored as 4 sec average values. The optical depth and multiple scattering factor values are recorded once per layer. There are up to 10 cloud layers in each cloud profile and up to nine aerosol layers in each aerosol profile; however, for the optical depth product, the nine layers are separated into eight elevated and one PBL height. For aerosol layers above 20 km are a possible of up to three layers but normally not reported since there were very few if any aerosol layers detected in the stratosphere.
The tropospheric layers would report up to five layers in the r_aer4_od parameter. So, r_aer4_od would contain the optical depths of the (up to 5) detected tropospheric aerosol layers. The PBL optical depth is stored separately in r_pbl4_od.

Optical depths for each layer have an associated composite flag variable (i_cld1_flag, i_aer4_flag and i_pbl4_flag)) that represents conditions in that layer. The composite flag is made up of two main components: a layer quality flag and a layer usage flag. In all cases, the quality flag is a categorized value of the percent error calculation. The usage flag designates layer type category. The "cloud multiple scattering warning flag" (i_cld1_mswf) is a measure of multiple scattering intensity and is based on the total column optical depth. One value is calculated for each 1 sec profile. The "estimated range delay" parameter is an estimate of the range offset (mm) caused by multiple scattering in the atmospheric column and is calculated for each 1 sec profile.

Parameters include the height, optical depth and range delay of blowing snow layers at 5 Hz resolution, the1064 nm total column optical depth (corrected for multiple scattering) at 40Hz and 1-second resolution, and the 1064 nm multiple scattering factor at 40Hz and 1-second resolution. The 1064 column optical depth is computed from the measured ocean surface reflectance (from the altimetry channel) and the "pristine" ocean reflectance computed from the Cox-Munk relationship of surface wind speed and ocean reflectance at 1064 nm. The 1064 nm column optical depth is valid only over the oceans and ice sheets. For the latter, the true or "pristine" surface reflectance is assumed to be 0.82. The "pristine reflectance" for the ocean is calculated at 1-second resolution and is also stored on the product.

Included on the GLAH11 product are two parameters for characterization of detected aerosol layers. The first parameter (r_aer4_sval_ratio) is the ratio of the 532 nm extinction to backscatter ratio (S532) to the 1064 nm extinction to backscatter ratio (S1064) for each detected aerosol layer. The second parameter (r_aer4_aod_ratio) is the ratio of 532 nm aerosol optical depth to 1064 nm aerosol optical depth for each detected aerosol layer. This provides a way for the user to obtain the 1064 aerosol optical depth if the 532 optical depth is known. These parameters were computed from an aerosol transport model at the University of Arizona. Also on GLAH11 are the true 532 extinction to backscatter ratio (r_aer4_sval1) and Aerosol true S Values use flag (i_aer4_sval_uf), both also on GLAH10.

Also the ID r_reflCor_atm parameter is an atmospheric attenuation correction factor to be applied to the surface reflectance value to account for the loss of energy of the laser pulse from the satellite to and from the surface. In release 33 a multiple scattering correction is applied to the computed attenuation. The calculation of atmospheric attenuation is from the 532 channel. This means that when the 532 laser energy drops below 5.5 mJ and it is daytime, or when 532 energy drops below 1.5 mJ (day and night), the attenuation calculation cannot be done and r_reflCor_atm is set to invalid. When the 532 laser energy is between 1.5 and 5.5 mJ, the attenuation calculation is only done for night data, and the daytime values of r_reflCor_atm will be invalid.