GLAS Atmospheric Products User Guide
November, 2008

Overview

The GLAS atmospheric measurements utilize a dual wavelength (532 nm 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 GLA02, Level-1B GLA07, and Level-2 GLA08 to GLA11 data products. These products are listed below.

- **GLA02**: 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 (532 nm and 1064 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.
- **GLA07**: Level-1B global backscatter data are provided at full instrument resolution. The product includes full resolution 532 nm (40.5 km to -1.5 km) and 1064 nm (20 km to -1.5 km) calibrated attenuated backscatter profiles at five 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 a rate of once per second. Data granules contain approximately 190 minutes (two orbits) of data.
- **GLA08**: 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 contain top and bottom heights of elevated aerosols from -1.5 km to 20.5 km at a 4-second sampling rate and from 20.5 km to 40.5 km at a 20-second sampling rate.
- **GLA09**: 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 nm channel data at 0.25 Hz and 1 Hz sampling interval and blowing snow over the polar regions.
- **GLA10**: 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.
- **GLA11**: Level-2 thin cloud/aerosol optical depths data contain thin cloud and aerosol optical depths as derived from the 532 nm 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 km. Also provided is the column optical depth over oceans from the 1064 nm channel.

GLAS has had a number of problems that have either eliminated or severely reduced the amount and quality of atmospheric data that it has obtained. This is especially true for the

532 nm channel; it was not operational 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 operational periods, the 532 nm data are unusable during the daytime but contain useful information in the nighttime portion of the orbits. As will be shown later in this document, many of the atmospheric parameters that are retrieved from GLAS use the 532 nm channel data. When the 532 nm laser energy drops below approximately 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 nm channel, while not as extensive as the 532 nm channel, are less affected by laser problems until laser energy drops below approximately 30 mJ, which occurred during the laser 3F operating period. The main effect of low laser energy is the decrease of the signal to noise ratio of the data that 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 nm	Data Quality 1064 nm	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 are derived. For more in-depth information on the contents of the products, the user is directed to the GLAS Atmosphere Data Dictionary (http://nsidc.org/data/docs/daac/glas_atmosphere/data_dictionary.html) for details. 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 http://www.csr.utexas.edu/glas/atbd.html. In addition, the user is encouraged to visit the

GLAS Atmospheric Data Product Web pages at http://glo.gsfc.nasa.gov. There, the user can find quick look images of atmospheric data acquired from all of the GLAS data operation periods and displays of various parameters contained in the GLAS atmospheric data products (GLA07 to GLA11). Since GLA02 contains raw uncalibrated data and consists mainly of engineering and system related parameters, it is not included in the user guide at this time.

GLA07 – Attenuated, Calibrated Backscatter

GLA07 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 nm channel profiles (i5_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 nm channel profiles (i5_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 nm (i40_g_bscs) and 1064 nm (i40_ir_bscs) begin at 10 km (bin 1) altitude and end at -1.5 km (bin 148). The GLAS instrument's fundamental data collection frequency is 40 Hz, but the data above 20.5 km are summed to one second onboard the satellite before being down linked. Eight shots are summed in the altitude region 10 to 20.5 km before being down linked, 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.

GLA07 also contains the molecular (Rayleigh) backscatter profiles for the 532 nm channel (i_g_mbscs) and 1064 nm channel (i_ir_mbscs) at a one-second resolution. The i_metFlg flag in GLA07 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 National Center for Environmental Prediction (NCEP) analysis fields interpolated in time and space to the spacecraft latitude and longitude. However, if for some reason the NCEP data are 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 GLA07 data product are the solar background measurements at 1, 5, and 40 Hz resolutions for the 532 nm channel (i1_g_bg, i5_g_bg, and i40_g_bg, respectively) and 5 and 40 Hz for the 1064 nm channel (i5_ir_bg and i40_ir_bg, respectively). The 532 nm background given in units of photons per bin is an accurate measurement of the 532 nm solar background, but the 1064 nm value does not represent the true background because the 1064 nm detector is AC coupled which means that the background is electronically subtracted from the 1064 nm measurement before the data are down linked.

Here, only a few of the quality flags are mentioned which can help the user identify good data. At byte offset 1900 and 1910, the 532 nm 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, at byte offset 54 is the LIDAR Frame Quality Flag (i_LidarQF) which indicates whether the 532 nm, Level-2 processing (GLA08 to GLA11) was performed. If the LIDAR Frame Quality Flag has a value of 0, then the 532 nm laser energy was sufficient for the Level-2 processing. If this flag is 1, the 532 nm processing occurred only for nighttime data because the laser energy has fallen below 5.5 mJ. If the 532 nm laser energy falls below 1.5 mJ, then the 532 nm 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 in all of the Level-2 atmospheric products. Note: This flag does not give any information about the status of the 1064 nm channel. For status of the 1064 nm laser energy use the i_ir_TxNrg_qf parameter.

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

Quality Flag	Data Quality	532 nm Energy	1064 nm 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 five 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; the calibration value is linearly interpolated between them at a one-second resolution. The 532 nm 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 to 30 percent. 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 nm calibration is determined by a combination of under flights with the Cloud Physics LIDAR (CPL) on the NASA ER-2 satellite and a technique which uses the ratio of the normalized 1064 nm return signal to the calibrated 532 nm attenuated backscatter from cirrus clouds. The CPL has a very well calibrated 1064 nm channel and is able to obtain coincident (with GLAS) measurements of clouds and aerosols which are then used as a calibration standard. It was found that the 1064 nm calibration did not change with time for the Laser 1 and Laser 3 observation periods, but it 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 i_g_cal_cof and i_ir_cal_cof for the 532 nm and 1064 nm channels, respectively. The 532 nm calibration is a three-word array where the first word is the calibration constant calculated from approximately a 30 km altitude. The second word contains the calibration constant calculated from an altitude of approximately 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 approximately 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 (i40_g_sat_prof and i5_g_sat_prof) correspond, bin-for-bin, to the 40 Hz and 5 Hz atmospheric profiles described above. The saturation profiles are binary flags that indicate that 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 "packed" in GLA07, meaning each bin of the profiles is represented by a single bit. Generally, saturation is not too problematic with the 532 nm data; but when it does occur, the calculated backscatter is likely less than it actually should be.

Note: The 532 nm LIDAR profiles in the GLAS Atmosphere Data Dictionary (http://nsidc.org/data/docs/daac/glas_atmosphere/data_dictionary.html) 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 (byte offset 70276) in the processing software. View the byte structure of this flag at (http://nsidc.org/data/docs/daac/glas_atmosphere/i_532attbs_flag.html) for more information. It turned out that this option was not used in practice (why?) and the 532 nm bins that were saturated were not replaced by 1064 nm data. The 1064 nm channel did not generally suffer from saturation, though it can occur. The maximum backscatter that the 1064 nm channel can measure is about 5.0 x 10^{-4} $m^{-1}sr^{-1}$.

GLA08 – PBL and Elevated Aerosol Layer Heights

The Level-2 GLA08 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 nm 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 two horizontal resolutions – 4 seconds and 5 Hz (GLA08 product variables i_LRpbl_ht and i_HRpbl_h, respectively). Each PBL top retrieval is given a confidence rating similar to the Elevated Aerosol Layer Flag (see below). The values range from 1 to 13 where 1 is the lowest confidence and 13 is the 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 at http://nsidc.org/data/docs/daac/glas_atmosphere/i_layhgt_flag.html 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 detect this, so over land at night if the boundary layer retrieval algorithm observes 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 nm channel) are grouped as tropospheric (below 20 km altitude) and stratospheric (above 20 km altitude), and they are reported as separate parameters on the product. The stratospheric (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, bytes 301-332) 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 NCEP analysis. Recently added to the GLA08 data product in Release-29 are aerosol layers detected from the 1064 nm channel at a 4-second resolution (i_Aer_ir_top and i_Aer_ir_bot). The sensitivity of the 1064 nm channel is considerably less than that of the 532 nm channel and will only detect the thicker elevated aerosol layers and more frequently the PBL aerosol. Note: When the 532 nm laser energy falls to the point where the 532 nm Level-2 processing is halted, the 1064-based parameters (aerosol layer height in this case) are still present.

GLA09 – Cloud Layer Heights

The Level-2 GLA09 product contains the cloud heights as detected from the 532 nm channel and from the 1064 nm channel. A maximum of 10 layers can be stored in the product. 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 resolutions (i_LRcld_top and bot, i_MRcld_top and bot, i_HRcld_top and bot, and i_FRcld_top and bot, respectively). It first averages four 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 two consecutive bins exceed the threshold; 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 two 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 has 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 four 1-second averaged profiles but, now, restricting the search to those altitude regions where layers were found from the 4-second averaged profile. If layers are found within the 1-second averaged 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 a small amount) 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 nm channel has significantly different sensitivity during day versus night. The Diurnal Flag indicates whether or not a given cloud layer detected from the 532 nm channel during nighttime would have been detected in daylight. These flags are i_LRCL_Flag, i_MRCL_Flag, i_HRCL_Flag, and i_FRCL_Flag where the four flags are low resolution (4-second), medium resolution (1-second), high resolution (5 Hz), and full resolution (40 Hz), respectively.

The 1064 nm cloud height algorithm is similar to the 532 nm algorithm but does not perform the search at 5 Hz. The clouds detected from the 1064 nm channel are reported at 4-second, 1-second, and 40 Hz resolutions (i_LRir_cld_top and bot, i_MRir_cld_top and bot, and i_FRir_cldtop and cldbot, respectively). 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 are detected in the 532 nm channel 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 only applies when the 532 nm laser energy is greater than approximately 10 mJ). Also in the GLA09 product are the temperature, pressure, and relative humidity at the height of cloud top and bottom for all resolutions of cloud detection.

New with Release-29 is that the GLA09 product now contains blowing snow detection at a 5 Hz resolution. This consists of four parameters: the height of the blowing snow layer (i_blow_snow_ht), the optical depth of the layer (i_blow_snow_od), the altimetry range delay introduced by the blowing snow layer (i_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 nm channel when available (when the LIDAR Frame Quality Flag discussed above is 0) and switches to the 1064 nm channel if 532 nm data are not good. Note: When the 532 nm laser energy falls to the point where the 532 nm Level-2 processing is halted, the 1064-based parameters (cloud layer height and blowing snow in this case) are still present.

GLA10 - Attenuated Corrected Backscatter and Aerosol Vertical Structure

GLA10 contains the optical inversion results from the 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 GLA08 and GLA09. However, for nighttime data, in addition to the extinction being computed within the detected layers, it is also computed starting at a 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 Release-29 and is known as the Free Troposphere Extinction Retrieval. This was implemented to detect 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. GLA10 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 GLA08 and GLA09. Cloud products such as backscatter (i_cld1_bs), extinction (i_cld1_ext), extinction-to-backscatter ratio (i_cld1_sval), and cloud layer tops (i_cld1_top) and bottoms (i_cld1_bot) are reported at a 1-second sampling rate, while aerosol extinction (i_aer4_bs_prof) and attenuation corrected backscatter (i_aer4_ext_prof) are reported at a 4-second rate only. PSCs are part of the aerosol category.

To obtain the complete vertical optical structure, merge the aerosol and cloud components. For every atmospheric layer detected by the 532 nm channel, 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 (i_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 the LIDAR signal was extinguished. The Free Troposphere Bottom Height Parameter (i_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 GLA10 but rather in GLA11. Each GLA10 record is four seconds 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-second averaged 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-second averaged 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-second cloud layers detected by GLA09 using the 532 nm channel) and up to nine aerosol layers in each aerosol profile (obtained from the 4-second aerosol layers detected by GLA08 using the 532 nm channel). 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 in GLA10.

All of the backscatter and extinction profiles have an associated composite flag variable (i_aer4_bs_flag and i_aer4_ ext _flag, respectively) 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.

See the GLAS Atmosphere Data Dictionary at http://nsidc.org/data/docs/daac/glas_atmosphere/data_dictionary.html for details of each record, including units and scaling factors.

GLA11 - Cloud and Aerosol Optical Depths

GLA11 contains the layer-by-layer optical depth retrievals from the GLAS 532 nm atmospheric profiles for clouds (i_cld1_od) and aerosols (i_aer4_od). The PBL optical depth is stored separately in the variable i_pbl4_od. Polar stratospheric clouds are part of the aerosol category. The multiple scattering correction applied to the cloud (i_cld1_msf) and aerosol (i_aer4_msf) retrievals are stored in the product. To obtain the total column optical depth, add the aerosol and cloud components. For every atmospheric layer detected by the 532 nm channel, a multiple scattering flag reflects the current multiple scattering condition. Another useful parameter is the Total Column Aerosol Optical Depth (i_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 GLA10 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.

GLA11 contains top and bottom heights of all the layers that were optically processed, separated into cloud (i_cld1_top and bot) and aerosol (i_aer4_top and bot). All cloud products, including optical depth, multiple scattering factor, and layer tops and bottoms are reported at a 1-second sampling rate. These are the same layers as reported in GLA09. The aerosol products (for the same layers as reported in GLA08) are reported at a 4-second sampling rate.

The ground detection parameter (i_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 (i_cld1_msf) used to correct the cloud backscatter for the effects of multiple scattering is stored in GLA11. There is also a Multiple Scattering Correction Factor for the aerosol backscatter (i_aer4_msf). Each GLA11 record is four seconds 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-second averaged values, and the 532 nm aerosol layer data are stored as 4-second averaged 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 heights and one PBL height. Active layers are not necessarily grouped toward the front of the array sequence. For aerosols, the top three layer positions are reserved for layers above 20 km. These are normally blank (invalid) since there are very few if any aerosol layers detected in the stratosphere. Thus, the tropospheric layers start at position four in the i_aer4_od array, which is dimensioned at eight. The i_aer4_od array at positions 4, 5, 6, 7, and 8 would contain the optical depths of the (up to five) detected tropospheric aerosol layers. The PBL optical depth is stored separately in i_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-second profile. The Estimated Range Delay Parameter is an estimate of the range offset (in mm) caused by multiple scattering in the atmospheric column and is calculated for each 1-second profile.

Parameters new to Release-29 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 resolutions, and the 1064 nm multiple scattering factor at 40 Hz and 1-second resolutions. The 1064 nm 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. The pristine reflectance calculated at a 1-second resolution is also stored in the product.