ICESat-2 Algorithm Theoretical Basis Document for Atmosphere Gridded Products

Steve Palm

E. Thomas Northam

Version 3.1 [*Interim*]

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Contents

Tables

Change Log

August 21, 2018: Corrected the logic in Section 3.3.1. Changed the units in Tables 2 and 3 to fraction from percent. [Update note: former Tables 2 and 3 are now contained the current Table 5.]

February 26, 2019: Corrected mistake in blowing snow description, Section 3.4. Changed "if *bsnow_h* is greater than or equal to -2" to "if *bsnow_con* is greater than or equal to -2"

May 2019: in Section 3.1 added the check of "*layer_attr*" when constructing the global cloud fraction grid.

August 2019: Added Section 3.1.1 that defines a new parameter (Global Aerosol Fraction) to be added to ATL16 and ATL17. Added Section 3.8 which defines the new control parameters *week_obs_minimum* and *month_obs_minimum*, and replaced old Section 4.0 with a new section on smoothing of the images that are made from the data grids. In Section 4.0 the new control parameters *smooth_grid* and *center_weight* are described. Changed old Section 4.0 to Section 5.0. Added Section 6.0.

September 2019: ATBD Version 2.1. Added observation grids to both ATL16 and ATL17. Specified that smoothing is to be done only on the data to produce the images. The atmosphere gridded data parameters written on the product are not smoothed.

December 5, 2019: ATBD Version 2.2a. Modifications to certain entries in Section 5.0 Table 2 and Table 3 content. Clarification notes added to Sections 3.1, 3.1.1, and 3.2. Corrections made to text in Section 3.3.1 for definition of low, middle, and high layer altitude boundaries; similar corrections made to Section 5.0 Tables 2 and 3. [Update note: former Tables 2 and 3 are now contained the current Table 5.]

April 30, 2020: ATBD Version 3.0. Section 2: modified the grid sizes for the polar plots for both ATL16 and 17. Modified the grid size of the ATL16 global grid. Added Section 3.10 to identify the data parameters for which the average values would be computed, written to the product and displayed on the image. Tables 2 and 3 updated to show the average values written to the product. Section 3.2 – change of title to total column optical depth image. All changes since Version 2.2a are in red font.

May 7, 2020: ATBD Version 3.1 DRAFT. Contains changes to expand Section 3.10 Product Averages from reporting just the parameter average values to become Section 3.10 Product Statistical Values to include the gridded parameter minimum, maximum, and standard deviation values in addition to the average (now the mean) value. The modifications to accommodate the Section 3.10 requirements are also made to Tables 2 and 3 in Section 5.0. [Update note: former Tables 2 and 3 are now contained the current Table 5.]

May 12, 2020: Modifications to Tables 2 and 3 in Section 5.0, to divide the tables into Tables 2.1 and 3.1 containing the original content, and setting up Tables 2.2 and 3.2 to contain the newly added statistical reporting parameters.

June 3, 2020: ATBD Version 3.1b DRAFT. Added sub-section headings 5.1, 5.2, 6.1, and 6.2 for delineating ATL16 and ATL17 product information. Expanded parameter sections to include prototype code statements to illustrate and enumerate the textual specifications. Additional material and

annotations are included in this edition, including one additional table (Table 2) that collects together information on monthly and weekly global and polar grid cell sizes and associated array sizes.

References for the monthly and weekly global and polar grid cell size are modified to be expressed as "longitude-size by latitude-size" in degrees (e.g., 1.5x0.5 degrees for ATL17 polar grid cell size). This is done for consistency with grid dimensioning and indexing (i.e., (i,j) where i = the longitude size or index and j = the latitude size or index.

A new table, Table 3, is added for observation grid information. Original Table 2 that was divided into Table 2.1 and 2.2, is relabeled to Tables 4.1 and 4.2. Correspondingly, original Table 3 that was divided into Table 3.1 and 3.2 now becomes Tables 5.1 and 5.2. Original Table 4 becomes Table 6, and Table 5 becomes Table 7.

June 10, 2020: Version 3.1c DRAFT. Prior ATBD review comments are incorporated in this version.

Table 3 has been added to apply the new weekly and monthly global and polar longitude and latitude grid cells sizes to the linear arrays pertinent to longitude and latitude steps.

A major change to this version is changes to polar and global grid sizes for both weekly and monthly (polar only) products. Prior versions used a 1x1 degree grid for all monthly (ATL17) products and a 2x2 degree grid for all weekly products (ATL16). This version incorporates different grid sizes as shown in Table 2.

The Section 1.0 statement that the weekly ATL16 and the monthly ATL17 atmosphere gridded products contained the same parameters at different dimensions and frequencies, the addition of the new Table 2 containing the new grid longitude and latitude size and dimensions, and now the further addition of a new Table 3 showing the impact of the longitude and latitude sizes and dimensions of the linear arrays (i.e., single dimensions), now provide the opportunity to reduce the product description tables in Section 5.0. Consequently, Sub-section headings 5.1 and 5.2 have been removed, and the dual table pairs of Tables 4.1 and 4.2 and 5.1 and 5.2, have been replaced with Tables now numbered as Table 5, Gridded Products List of Gridded and Linear Parameters, Ancillary Data and Images, and Table 6, Gridded Products List of Statistical Parameters.

Table 5 has been expanded to use the ATL16 and ATL17 global and polar grid dimension sizes in Table 2, and the linear array dimension sizes in Table 3 to discriminate the weekly gridded parameter array dimensions and linear array dimensions from those of the monthly gridded parameter arrays and linear arrays in this general table.

The previous Table 3, Gridded Products Observation Grid Parameters has now become Table 4. The previous Table 6, ATL17 Data Product ATL09 Composition by Month has become Table 7, and previous Table 7, ATL16 Data Product ATL09 File Composition by Month and Week has been relabeled as Table 8.

A major change now is the addition of the high-rate blowing snow frequency atmosphere gridded parameter in addition to the existing blowing snow frequency that was based upon usage of the low-rate profile blowing snow height and blowing snow confidence.

June 11, 2020: content changes to Section 3.4 text to clearly indicate the incidence now of both the low-rate and high-rate blowing snow frequency gridded parameters.

June 12, 2020; and June 15, 2020: Version 3.1: Tables 5 and 6 are supplemented with a new table that now becomes Table 6, and the existing Table 6 becomes Table 7. Tables 7 and become Tables 8 and 9.

Statements were added to reference the global parameter array index origin (0,0) to the lower left corner of the grid layout and array. Similar notations were added to reference the South polar parameter array index origin (0,0), also to the lower left corner of the grid layout and array. The North polar parameter array index origin (0,0) mirrors the South polar array with reference at upper left corner of the grid layout and array. Graphic images and text have been added as Attachments A-3, A-4, and A-5.

Control parameters, that had been omitted in the recent set op updates, have been returned in Table. 6. Group identification headers have been added back in to Tables 5, 6, and 7. Parameter names from these tables are now included as references within each algorithm description section. Final text additions and comments have been included or addressed.

Removal of red and blue font colors used to designate sets of changed text or added content. Incorporation of font color and type-setting to highlight and increase visibility of formal input ATL09 profile product parameters and output ATL16/ATL17 gridded product parameters.

June 19, 2020: Version 3.1: Added "red" font color back in to original state to discriminate changes.

July 16-17, 2020: Version 3.1 [*Interim*]: Changes to Table 4.

July 23, 2020: Version 3.1 [*Interim*]: Changes to Table 4.

August 12, 2020: Version 3.1 [*interim*]: change "asr_obs_grid" to "global_asr_obs_grid" in Table 5. to match the revised entry in Table 4.

Terminology

The term "INVALID" appears throughout the text of this document relative to values encountered in the input process data associated with ICESat-2 ATLAS Level-3A data obtained from the ATL09 standard data product, and the output atmosphere gridded standard data products ATL16 and ATL17. In a generic context INVALID represents missing or empty input profile data, and missing or empty output gridded parameter cells. The class of INVALID values pertaining to missing or empty profile values or missing or empty gridded parameter cell values are identified in the input HDF5 products or output HDF5 products by the Name "_FillValue". In application, INVALID or _FillValue locations contain numerical values that are "huge", i.e., the largest number (not infinity) representable within the 1-byte, 2-byte, and 4-byte integer type, the 32-bit (4-byte) floating point (or real) type, or 64-bit (8-byte) real (or double precision) type. The bottom line here is this, INVALID values should be ignored and exempted from any data usage or algorithm processing consideration.

Used within the product description tables, "N/A" generally means "Not Applicable".

Parentheses "()" are used with the presentation of ATL09 profile parameters to indicate a data array at the profile rate (i.e., 25 Hz for high-rate profile data, or 1 Hz for low-rate profile data). The notation "(,)" or "(,n)" would be used to indicate a 2-dimensional profile parameter array. As examples, the high-rate (25 Hz) profile parameter "*cloud_flag_atm*" will be presented as "*cloud_flag_atm* ()"; the 2-dimesnional profile parameter "*layer_attr*" will be presented as either "*layer_attr* (,n)" or "*layer_attr* (,)".

For the output products ATL16/ATL17, 2-dimensional atmosphere gridded parameters will generally be represented with the indices (i,j) or (,). Single-dimensional linear parameter arrays with generally be represented with indices (i) and (j), or simply (). As examples, "global_cloud_frac" will appear as "global_cloud_frac (i,j)", "global_aerosol_frac" may be represented as "global_aerosol_frac (,)", "global_grid_lon" will appear as "global_grid_lon (i)", and "spolar_grid_lat" will appear as "spolar_grid_lat (j)" or "spolar_grid_lat ()".

Typographical Conventions

Italics are used to specifically denote parameters identified from the input ATL09 calibrated backscatter profile and atmospheric layer characteristics data products or to be contained within the output weekly ATL16 or monthly ATL17 atmosphere gridded data products. For example: the _solar_elevation_ parameter is obtained from the ATL09 product, and the _data_type_flag_ is written out to the ATL16 and ATL17 data products. Note that generic atmosphere gridded parameter references such as "global cloud fraction" are not italicized.

Application of font color and type-setting to highlight and increase visibility (contrast) of formal input ATL09 profile product parameters and generated output ATL16/ATL17 gridded product parameters.

product parameter name forms	color	type set	use	product	dimension	source/destination description
cloud_flag_atm *cloud_flag_atm* ()	blue 0000FF	*italics*	input	ATL09	single-dimension profile array	Level-3A calibrated backscatter profile and atmospheric layer characteristics
layer_attr *layer_attr* (,) *layer_attr* (,n)	blue 0000FF	*italics*	input	ATL09	two-dimension profile array	Level-3A calibrated backscatter profile and atmospheric layer characteristics
data_type_flag	dark green 006600	*italics*	input/ output	control ATL16/ ATL17	single location variable	Level-3B atmosphere gridded products
global_cloud_frac global_cloud_frac (,) global_cloud_frac (i,j)	dark green 006600	none	output	ATL16/ ATL17	two-dimension grid array	Level-3B atmosphere gridded products

product parameter name forms	color	type set	use	product	dimension	source/destination description
global_grid_lon global_grid_lon () global_grid_lon (i)	dark green 006600	none	output	ATL16/ ATL17	single-dimension grid array	Level-3B atmosphere gridded products

It is noted that the usage of font color and type-setting is not applied to the generic atmosphere profile parameters in text such as "solar elevation", "surface signal", or "blowing snow height", generic atmosphere gridded parameters presentation such as "Global Cloud Fraction" or "north polar ground detection frequency", or for the informal generic terms appearing in the pseudocode exhibits such as "low-rate blowing snow detection grid" or "high-rate blowing snow frequency polar grid".

1.0 Introduction

The atmosphere gridded products consist of the Level-3B (L3B) products ATL16 and ATL17. ATL16 will be a weekly product and ATL17 will be generated monthly. The same atmospheric information will be on both products. The content of both products will include: global cloud fraction, global aerosol fraction, total column optical depth over water, polar cloud fraction, blowing snow frequency, apparent surface reflectivity, and ground detection frequency. The polar cloud fraction will be broken into six (6) separate grids representing high, low, middle, transmissive, opaque and total cloud fraction for each hemisphere.

The HDF product files will contain the gridded fields of the above parameters as 2-dimensional arrays and also images of these fields plotted on a map of the respective region. ATL16 weekly products will be generated on a 3x3-degree global grid and 3x1-degree polar grids, and ATL17 monthly products on a 1x1 degree global grid and 1.5x0.5-degree polar grids. Table 1 lists the various atmospheric parameters contained in the L3B products, the type of grid used and the frequency for each. Table 2 provides summary details of the grid cell longitude and latitude sizes and the array dimensions associated with the weekly and monthly global and polar atmosphere gridded parameters. Table 3 applies the grid cell longitude and latitude sizes to weekly and monthly global and polar linear (single-dimensioned) longitude and latitude arrays.

Table 1. Level-3B Atmosphere Gridded Parameters and Grid Type and Frequency

Atmospheric Parameter	Type of Grid	Frequency	
		ATL16	ATL17
Global Cloud Fraction	Global	weekly	monthly
Global Aerosol Fraction	Global	weekly	monthly
Total Column Optical Depth	Global	weekly	monthly
Polar Cloud Fraction	Polar	weekly	monthly
Blowing Snow Frequency	Polar	weekly	monthly
Apparent Surface Reflectivity	Global and Polar	weekly	monthly
Ground Detection Frequency	Global and Polar	weekly	monthly

Table 2. Level-3B Atmosphere Gridded Products Parameters Grid Sizes and Dimensions

ATM Product	Coverage Period	Grid Type	Grid Size (degrees)			Grid Dimension (i,j) = (lon,lat)
			Longitude	Latitude	Combined	
ATL16	weekly	Global	3.0	3.0	3.0x3.0 *or* 3x3	(120,60)
ATL16	weekly	Polar	3.0	1.0	3.0x1.0 *or* 3x1	(120,30)
ATL17	monthly	Global	1.0	1.0	1.0x1.0 *or* 1x1	(360,180)
ATL17	monthly	Polar	1.5	0.5	1.5x0.5	(240,60)

Table 3. Level-3B Atmosphere Gridded Products Linear Parameters Array Sizes and Dimensions

ATM Product	Coverage Period	Grid Type	Array Size (degrees)		Longitude Dimension (i) = (lon)	Latitude Dimension (j) = (lat)
			Longitude	Latitude		
ATL16	weekly	Global	3.0	3.0	(120)	(60)
ATL16	weekly	Polar	3.0	1.0	(120)	(30)
ATL17	monthly	Global	1.0	1.0	(360)	(180)
ATL17	monthly	Polar	1.5	0.5	(240)	(60)

A control parameter will be installed as a default within the code, with an override read in from the execution control file that will establish whether both night and day data are included in the generation of the product or only night data. The night only data is determined from the ATL09 parameter *solar_elevation* applied as filter. If it is less than 0.0, then it is considered night data. This control parameter will be included on the product as parameter *data_type_flag* within the product group "/ancillary_data/atmosphere". A value of zero (0) means to use both day and night data to generate the products, and one (1) will mean to use only night data. The coded default value will be zero (0) for processing day and night data; a control file override value of one (1) will process only night data.

In general, the atmosphere gridded parameters derive from selected parameters collected from the ATL09 Level-3A calibrated backscatter profile and atmospheric layer characteristics data. The gridded parameters are rational, expressed as the ratio of a logically-filtered profile observation count or ATL09 parameter summation as an accumulated numerator value for each cell in a particular grid, divided by a denominator that is total count based primarily on 25 Hz high-rate profile data for each cell or on the accepted observation count for the average atmosphere gridded parameter computation. The cell numerator running counts or running sums are discriminated by logic application of specified flags, attributes, and quality flags. Once all ATL09 dataset input has been assimilated, counted and/or summed within the numerator and denominator grid cells as appropriate, the rational division of numerator cells by denominator cells for the grid parameter array is performed to generate each atmosphere gridded parameter. The cells of the denominator grid consist of the count of 25 Hz observations, with the filtered count exceptions being average apparent surface reflectance and blowing snow frequency. For the record, blowing snow frequency deviates from this description in that the low-rate 1 Hz profile data is used. Also it is noted that the set of parameters collected and reported as observation counts in Section 3.9 are actually the denominator total observation count or the number of observations used in the summation grid cell contents. NOTE: with this ATBD version, high-rate blowing snow height and confidence profile data is now assimilated for accumulation and computation of the high-rate blowing snow frequency.

The following pseudocode content presents how the night only data selection logic would be generically applied to each global and polar gridded parameter. Section 2.0 addresses the (i,j) array indexing and indices. NOTE: the input high-rate parameter *solar_elevation* () does not contain INVALID values in the profile observations.

the pseudocode below represents the generic (typical) logic for night only data filtering of ATL09 profile parameter data including selected observations for counting or summation in the numerator grid, and the total available observation count collected in the denominator grid, for all 25 Hz (high-rate) profile observations ():	

for every 25 Hz profile observation ()
  for *data_type_flag* = 1
    for *solar_elevation* () => 0.0
      next 25 Hz profile observation ()
    else
      for filtering criteria met
        for profile observation counting
          add 1 to parameter counter grid (i,j)   [numerator]
        for profile observation running sum
          add parameter to summation grid (i,j)   [numerator]
      add 1 to total observation grid (i,j)   [denominator]
  next 25 Hz profile observation ()
	process night only data
	indicates daylight observation
	skip to next profile observation
	this is night data, process
	process this profile observation
	for observation counting
	increment counter grid
	for observation running sum
	add value to summation grid
	increment total observation grid
	cycle through all observations

the pseudocode below represents the generic (typical) logic for filtering of ATL09 profile parameter data including selected observations for summation in the numerator grid, and the filtered available observation count collected in the denominator grid, for all 1 Hz (low-rate) profile observations () in the case of low-rate blowing snow frequency:	

for *data_type_flag* = 1   process night only data
    interpolate 25 Hz profile *solar_elevation* () to 1 Hz profile *lo_rate_solar_elevation* () using 1 Hz
                                   lo_rate_atm_time ()	

for every 1 Hz profile observation ()
    for *data_type_flag* = 1
      for *lo_rate_solar_elevation* () => 0.0
        next 1 Hz profile observation ()
      else
 	
        for detection filtering criteria met
          add 1 to detection grid (i,j)   [numerator]
        for observation filtering criteria met
          add 1 to observation grid (i,j)   [denominator]
    next 1 Hz profile observation ()
	process night only data
	indicates daylight observation
	skip to next profile observation
	this is night data, process
	
	test detection grid criteria
	increment detection grid
	test observation grid criteria
	increment sel. observation grid
	cycle through all observations

2.0 Global and Polar Grids

For the atmosphere gridded products presented here, simple grids are used at various resolutions. For the monthly (ATL17) product, the global grid and the polar grids the longitude by latitude sizes are included in Table 2. Similarly, the weekly product (ATL16) global grid and the polar grids longitude and latitude sizes are found in Table 2. Some atmospheric fields are produced on a global grid while others are produced on polar grids that cover only the area poleward of 60N or 60S. Two atmospheric parameters, apparent surface reflectivity and ground detection frequency, are produced on both global and polar projection arrays. Array dimensions for the monthly global grids (i,j) and the weekly global

grids (i,j) are also included in Table 2. Similarly, monthly polar grids (i,j) dimensions and weekly polar grids (i,j) dimensions are supplied in Table 2. The latitudes and longitudes of the various grids will be included on both products as single-dimensioned linear arrays (described in Table 5). NOTE: in the (i,j) grid cell indices, i is the longitude index and j is the latitude index.

The underlying assumptions for global atmosphere gridded algorithms are that longitude goes from -180 to 180 and latitude goes from -90 to 90 degrees; and that the (i,j) indices start at (0,0) for (longitude=-180, latitude=-90). For the global gridded atmosphere parameter array the origin (0,0) occurs at the lower left corner. A graphical illustration of the indexing scheme for an example global gridded array showing the cell layout including the origin and reference is provided in Attachment A-3.

The monthly and weekly **global grid indices** are computed from *longitude* and *latitude* coordinates as follows:

i = int(*longitude*+180.0), j = int(*latitude*+90.0)	for the 1x1 degree grid	global monthly grid, ATL17 product
i = int(*longitude*/3+60.0), j = int(*latitude*/3+30.0)	for the 3x3 degree grid	global weekly grid, ATL16 product

Polar monthly grids and the polar weekly grids will be dimensioned according to Table 2. The longitude span is expressed in the assumptions above. North polar latitude goes from 90 down to 60 degrees. The North polar (i,j) indices start at (0,0) for (longitude=-180, latitude=90). For the North polar gridded atmosphere parameter array the origin (0,0) occurs at the upper left corner. A graphical illustration of the indexing scheme for an example North polar gridded array showing the cell layout including the origin and reference is provided in Attachment A-4.

The **North polar grid indices** are computed as:

i = int(*longitude*/1.5+120.0), j = int(180.0-*latitude**2)	for the 1.5x0.5-degree grid, where *latitude* is >= 60.0	North polar monthly grid, ATL17 product
i = int(*longitude*/3.0+60.0), j = int(90.0-*latitude*)	for the 3x1 degree grid, where *latitude* is >= 60.0	North polar weekly grid, ATL16 product

Again, the longitude span is expressed in the assumptions above. South polar latitude goes from -90 up to -60 degrees. The South polar (i,j) indices start at (0,0) for (longitude=-180, latitude=-90). For the South polar gridded atmosphere parameter array the origin (0,0) occurs at the lower left corner. A graphical illustration of the indexing scheme for an example South polar gridded array showing the cell layout including the origin and reference is provided in Attachment A-5.

The **South polar grid indices** are computed as:

i = int(*longitude*/1.5+120.0), j = int(180.0+*latitude**2)	for the 1.5x0.5-degree grid, where *latitude* is <= -60.0	South polar monthly grid, ATL17 product
i = int(*longitude*/3.0+60.0), j = int(90.0+*latitude*)	for the 3x1 degree grid, where *latitude* is <= -60.0	South polar weekly grid, ATL16 product

3.0 Product Definitions

3.1 Global Cloud Fraction

This atmospheric parameter ("global_cloud_frac", i.e., from Table 5, typical) is displayed on a global grid. Define a "cloud counter grid" [i.e., the numerator grid] and a "total observation grid" [i.e., the denominator grid]. The ATL09 product contains the parameter "*cloud_flag_atm*" which is the number of layers detected for a given 25 Hz profile (note: up to possibly 10 layers). When this parameter is > 0 AND the parameter *layer_attr* = 1 for any layer (i.e., 1=cloud layer attribute), the cloud counter grid box associated with the current location (i,j) indices (computed as in Section 2.0 above) is incremented by one (1) for that grid box. The total observation grid box count is incremented by one (1) for every 25 Hz profile regardless of the value of the product parameter *cloud_flag_atm* () or *layer_attr* (,). NOTE: the input parameters *cloud_flag_atm* () and *layer_attr* (,n) <u>do not</u> contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required.

NOTE that the "cloud counter grid" is incremented only once regardless of the number of cloud layers detected after the first determined cloud layer.

the pseudocode below represents the conditional logic for incrementing the "*cloud counter grid*", i.e., the numerator grid, for all 25 Hz (high-rate) profile observations ():	
for 25 Hz *cloud_flag_atm* () > 0 and *layer_attr* (,n) = 1 cloud counter grid (i,j) = cloud counter grid (i,j) + 1	a cloud layer is detected only for the first *layer_attr* (,n) = 1
the pseudocode below represents the logic for incrementing the "*total observation grid*", i.e., the denominator grid, for all 25 Hz (high-rate) profile observations ():	
for every 25 Hz profile total observation grid (i,j) = total observation grid (i,j) + 1	

After reading the input ATL09 files for the period in question, the cloud counter grid [the numerator grid] is divided by the total observation grid [the denominator grid] to obtain a global grid of cloud fraction. For cases where the number of total observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the cloud fraction to INVALID.

the pseudocode below represents the conditional logic for calculating the "*global cloud fraction grid*" by division of the "*cloud counter grid*", i.e., the numerator grid, by the "*total observation* grid", i.e., the denominator grid, for either the weekly or the monthly atmosphere gridded data product:

for total observation grid (i,j) => *_obs_minimum
 	
                                    cloud counter grid (i,j)
    global cloud fraction grid (i,j)   = -----------------------------------
                                      total observation grid (i,j)
else
    global cloud fraction grid (i,j)   = INVALID

NOTE: *_obs_minimum represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

NOTE that the title of the image made from these data was briefly "Global Cloud and Aerosol Layer Fraction" (as implemented with ATBD Version 1.2) and was required to be changed to "Global Cloud Fraction" after the changes with ATBD Version 2.0 were made, which implemented cloud/aerosol discrimination via the *layer_attr* parameter described above.

3.1.1 Global Aerosol Fraction

This atmospheric parameter ("global_aerosol_frac") is displayed on a global grid. Define an "aerosol counter grid" [i.e., the numerator grid] and a "total observation grid" [i.e., the denominator grid]. The ATL09 product contains the parameter "*cloud_flag_atm*" which is the number of layers detected for a given 25 Hz profile (up to 10 layers). When this parameter is > 0 AND the parameter *layer_attr* = 2 for any layer (i.e., 2=aerosol layer attribute), the aerosol counter grid box associated with the current location (i,j) indices (computed as in Section 2.0 above) is incremented by one (1) for that grid box. Note that when *cloud_flag_atm* > 1, the *layer_attr* flag must be checked for each of the layers. If any one of them is equal to 2, then the aerosol counter is incremented. The total observation count grid box is incremented by one (1) for every 25 Hz profile regardless of the value of the product parameter *cloud_flag_atm* () or *layer_attr* (,). NOTE: the input parameters *cloud_flag_atm* () and *layer_attr* (,n) <u>do not</u> contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required.

NOTE that the "aerosol counter grid" is incremented only once regardless of the number of aerosol layers detected after the first determined aerosol layer.

the pseudocode below represents the conditional logic for incrementing the "*aerosol counter grid*", i.e., the numerator grid, for all 25 Hz (high-rate) profile observations ():	
for 25 Hz *cloud_flag_atm* () > 0 and *layer_attr* (,n) = 2 aerosol counter grid (i,j) = aerosol counter grid (i,j) + 1	an aerosol layer is detected only for the first *layer_attr* (,n) = 1
the pseudocode below represents the logic for incrementing the "*total observation grid*", i.e., the denominator grid, for all 25 Hz (high-rate) profile observations ():	
for every 25 Hz profile total observation grid (i,j) = total observation grid (i,j) + 1	

After reading the input ATL09 files for the period in question, the aerosol counter grid is divided by the total observation grid to obtain a global grid of aerosol fraction. For cases where the number of total

observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the aerosol fraction to INVALID.

the pseudocode below represents the conditional logic for calculating the "*global aerosol fraction grid*" by division of the "*aerosol counter grid*", i.e., the numerator grid, by the "*total observation* grid", i.e., the denominator grid, for either the weekly or the monthly atmosphere gridded data product:

for total observation grid (i,j) => *_obs_minimum
 	
                                               aerosol counter grid (i,j)
    global aerosol fraction grid (i,j)   =   ------------------------------------
                                          total observation grid (i,j)
else
    global aerosol fraction grid (i,j)   =   INVALID

NOTE: *_obs_minimum represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

The title of the image made from these data is "Global Aerosol Fraction".

3.2 Total Column Optical Depth

On the ATL09 product is a parameter called *column_od_asr* which is the total column optical depth estimated from the apparent surface reflectance. This parameter is computed over the entire globe, but for this product we only want to grid the data over water. Global grids are established as in Section 3.1 above. If the total column optical depth is not INVALID (i.e., it will be INVALID when there is no ground return detected), and if the return is over a water surface (i.e., if the ATL09 product parameter *column_od_asr_qf* is = 4, indicates over water), then it (i.e., *column_od_asr*) is added to the total column optical depth grid box [i.e., the numerator grid] corresponding to the current location (i,j) indices (value computed as in Section 2.0 above), and the corresponding over water total observation counter grid box [i.e., the denominator grid] is incremented by one (1). NOTE: the parameters *column_od_asr* () will contain INVALID values and *column_od_asr_qf* () may contain INVALID values in the profile observations. Therefore, INVALID input profile observation exception is required.

the pseudocode below represents the logic for selected summation of the "*total column optical depth grid*", i.e., the numerator grid, and for selected increment of the "*total water observation grid*", i.e., the denominator grid, based on the filtered and accepted 25 Hz (high-rate) profile observations ():

for 25 Hz profile *column_od_asr* () ≠ INVALID and *column_od_asr* () > 0 and *column_od_asr_qf* () = 4
    total column optical depth grid (i,j) = total column optical depth grid (i,j) + *column_od_asr* ()
    total water observation grid (i,j) = total water observation grid (i,j) + 1

After all of the ATL09 granules have been read in, the total column optical depth grid is divided by the total water observation counter grid (where the water observation counter grid is > 0) to establish the average total column optical depth over water ("global_column_od") for the period in question. For cases where the number of total water observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the average total column optical depth to INVALID.

<table>
<tr><td>the pseudocode below represents the conditional logic for calculating the "*global average total column optical depth grid*" by division of the "*total column optical depth grid*", i.e., the numerator grid, by the "*total water observation grid*", i.e., the denominator grid, for either the weekly or the monthly atmosphere gridded data product:</td></tr>
<tr><td>

for water observation grid (i,j) => *_obs_minimum

                                         total column optical depth grid (i,j)

    global average total column optical depth over water grid (i,j) = --

                                         total water observation grid (i,j)

else

    global average total column optical depth over ocean grid (i,j) = INVALID
</td></tr>
<tr><td>NOTE: *_obs_minimum represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product</td></tr>
</table>

As indicated in Section 1.0 and Table 2 above, the low-resolution global grid size and dimension is used for the weekly product and the high-resolution global grid size and dimension is used for the monthly product.

NOTE that the 0 to 1.5 range constraint is applied to the image and not to the parameter gridded array values. Note also that the title of the image written to the product for this parameter is to be "Global (Over Water) Total Column Optical Depth (0-1.5)".

3.3 Polar Cloud Fraction

3.3.1 High, Middle, Low and Total Cloud Fraction

For each observation period (weekly/monthly) eight (8) separate polar grids are established that cover the latitude range 60N to 90N and 60S to 90S ("npolar_highcloud_frac", "npolar_midcloud_frac", "npolar_lowcloud_frac", "npolar_totalcloud_frac", "spolar_highcloud_frac", "spolar_midcloud_frac", "spolar_lowcloud_frac", and "spolar_totalcloud_frac"). For the polar regions, four (4) cloud fraction grids are created for each hemisphere. Grid 1 will contain the fraction of clouds that occur below and up to and including 4 km altitude. Grid 2 will contain the cloud fraction for clouds above 4 km and up to and including 8 km. Grid 3 will contain the cloud fraction for clouds that occur above 8 km. Grid 4 will represent total cloud fraction. So, there are four (4) grids for each polar region (four (4) North and four (4) South). The grids are populated in the same way as described in Section 3.1, except the low, middle, and high layers are segregated by the altitude of the cloud layer top.

NOTE that *layer_attr* has to be equal to 1 for the layer to be a cloud. The top height of the layers is contained in the ATL09 parameter "*layer_top*", which is dimensioned at 10 but the elements of *layer_top* will only be defined up to the number of layers found. The number of layers found is obtained from the ATL09 parameter *cloud_flag_atm*. Thus, if *cloud_flag_atm* is = 0, that would mean that there were no clouds found in this profile. The *layer_top* (1) up to *layer_top* (*cloud_flag_atm*) are examined to obtain the top heights of the various cloud layers. NOTE: the parameters *cloud_flag_atm* () and *layer_attr* (,n) <u>do not</u> contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required for these parameters. The parameter *layer_top* (,n) will contain INVALID values in the profile observations. Therefore, INVALID input profile observation exception is required for this parameter.

Assuming *cloud_flag_atm* is > 0, then for each value of x from 1 to *cloud_flag_atm*:

   if any *layer_top (x)* is <= 4 km AND *layer_attr* = 1, then increment the counter for Grid 1.

   if any *layer_top (x)* is > 4 km and <= 8 km AND *layer_attr* = 1, then increment the counter for Grid 2.

   if any *layer_top (x)* is > 8 km AND *layer_attr* = 1, then increment the counter for Grid 3.

   if *cloud_flag_atm* is > 0 AND *layer_attr* = 1 for any layer, then increment the counter for Grid 4.

Note that each of the four (4) counter grids for each polar region are to be incremented (at most) only once per 25 Hz profile. This means if there are two cloud layers, between 4 and 8 km for example, the counter for Grid 2 is incremented only once, not twice.

A separate observation counter grid is established and the appropriate grid box is incremented for every 25 Hz profile regardless of the value of the value of *cloud_flag_atm*. Typically for the northern hemisphere or the southern hemisphere:

the pseudocode below represents the conditional logic for incrementing the "*low (Grid 1), middle (Grid 2), high (Grid 3), and total (Grid 4) cloud counter grids*", i.e., the numerator grids, for all 25 Hz (high-rate) profile observations ():

for 25 Hz profile *cloud_flag_atm* () > 0
      for x from 1 to *cloud_flag_atm*
            for *layer_top* (,x) <= 4 and *layer_attr* (,x) = 1
                  Grid 1 (low cloud) counter grid (i,j) = Grid 1 (low cloud) counter grid (i,j) + 1
            for *layer_top* (,x) > 4 and *layer_top* (x) <= 8 and *layer_attr* (,x) = 1
                  Grid 2 (middle cloud) counter grid (i,j) = Grid 1 (middle cloud) counter grid (i,j) + 1
            for *layer_top* (,x) > 8 and *layer_attr* (,x) = 1
                  Grid 3 (high cloud) counter grid (i,j) = Grid 3 (high cloud) counter grid (i,j) + 1
      for *layer_attr* (,n) = 1
            Grid 4 (total cloud) counter grid (i,j) = Grid 4 (total cloud) counter grid (i,j) + 1

NOTE: a detected cloud layer counter grid is increment only for the first *layer_attr* (,n) = 1
the pseudocode below represents the logic for incrementing the "*total observation grid*", i.e., the denominator grid, for all 25 Hz (high-rate) profile observations ():
for every 25 Hz profile   total observation grid (i,j) = total observation grid (i,j) + 1

All four grids are then divided by the total observation grid (where it is > 0) to obtain the various cloud fractions (four (4) cloud fractions for each hemisphere). For cases where the number of observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the cloud fraction to INVALID.

the pseudocode below represents the conditional logic for calculating the "*low (Grid 1), middle (Grid 2), high (Grid 3)m and total (Grid 4) polar cloud fraction grids*" by division of the "*low (Grid 1), middle (Grid 2), high (Grid 3)m and total (Grid 4) cloud counter grids*", i.e., the numerator grids, by the "*total observation* grid", i.e., the denominator grid, for either the weekly or the monthly atmosphere gridded data product:

```
for total observation grid (i,j)  =>  *_obs_minimum
```

$$\text{Grid 1 (low) polar cloud fraction grid (i,j)} = \frac{\text{Grid 1 (low cloud) counter grid (i,j)}}{\text{total observation grid (i,j)}}$$

$$\text{Grid 2 (middle) polar cloud fraction grid (i,j)} = \frac{\text{Grid 2 (middle cloud) counter grid (i,j)}}{\text{total observation grid (i,j)}}$$

$$\text{Grid 3 (high) polar cloud fraction grid (i,j)} = \frac{\text{Grid 3 (high cloud) counter grid (i,j)}}{\text{total observation grid (i,j)}}$$

$$\text{Grid 4 (total) polar cloud fraction grid (i,j)} = \frac{\text{Grid 4 (total cloud) counter grid (i,j)}}{\text{total observation grid (i,j)}}$$

```
else
     Grid 1 (low) polar cloud fraction grid (i,j)  =  INVALID
     Grid 2 (middle) polar cloud fraction grid (i,j)  =  INVALID
     Grid 3 (high) polar cloud fraction grid (i,j)  =  INVALID
     Grid 4 (total) polar cloud fraction grid (i,j)  =  INVALID
```

NOTE: *_obs_minimum* represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

3.3.2 Transmissive and Opaque Cloud Fraction

Four polar grids are established, two for each hemisphere ("npolar_transcloud_frac", "npolar_opaquecloud_frac", "spolar_transcloud_frac", and "spolar_opaquecloud_frac"). As in Section 3.3.1, the grids will cover the latitudes 60N to 90N and 60S to 90S. The ATL09 product contains the parameter "*cloud_flag_atm*" which is the number of cloud layers detected for a given 25 Hz profile. When this parameter is > 0, AND the ATL09 parameter "*surface_sig*" is > 0 AND "*layer_attr*" = 1 for any layer, then the current grid box for the transmissive cloud counter grid is incremented. When the parameter "*cloud_flag_atm*" is > 0 AND the parameter "*surface_sig*" is = 0 AND "*layer_attr*" = 1, then the current grid box for the opaque cloud counter grid is incremented. As before, for each observation (25 Hz profile) the current total observation grid box is incremented by one (1). NOTE: the input parameters *cloud_flag_atm* (), *layer_attr* (,n), and *surface_sig* () do not contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required. Typically for the northern hemisphere or the southern hemisphere:

the pseudocode below represents the conditional logic for incrementing the "*transmissive cloud counter grid*" *and* "*opaque cloud counter grid*", i.e., the numerator grids, for all 25 Hz (high-rate) profile observations ():

```
for 25 Hz profile cloud_flag_atm () > 0
    for surface_sig ()  > 0.0 and layer_attr (,n) = 1
        transmissive cloud counter grid (i,j) = transmissive cloud counter grid (i,j) + 1
    for surface_sig ()  = 0.0 and layer_attr (,n) = 1
        opaque cloud counter grid (i,j) = opaque cloud counter grid (i,j) + 1
```

NOTE: a detected cloud layer counter grid is increment only for the first *layer_attr* (,n) = 1
the pseudocode below represents the logic for incrementing the "*total observation grid*", i.e., the denominator grid, for all 25 Hz (high-rate) profile observations ():

```
for every 25 Hz profile
    total observation grid (i,j) = total observation grid (i,j) + 1
```

When the period in question (weekly/monthly) has been analyzed, divide the transmissive and opaque cloud counter grids by the total observation grid (for all observation grid boxes > 0). For cases where the number of observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the cloud fraction to invalid.

the pseudocode below represent the conditional logic for calculating the "*transmissive polar cloud fraction grid*" and "*opaque polar cloud fraction grid*" by respective division of the "*transmissive cloud counter grid*" and "*opaque cloud counter grid*", i.e., the numerator grids, by the "*total observation* grid", i.e., the denominator grid, for either the weekly or the monthly atmosphere gridded data product:

```
for total observation grid (i,j)  => *_obs_minimum
                                         transmissive cloud counter grid (i,j)
    transmissive polar cloud fraction grid (i,j)  =  ----------------------------------------------
                                               total observation grid (i,j)

                                         opaque cloud counter grid (i,j)
    opaque polar cloud fraction grid (i,j)  =  -------------------------------------------
                                           total observation grid (i,j)
else
    transmissive polar cloud fraction grid (i,j)  =  INVALID
    opaque polar cloud fraction grid (i,j)  =  INVALID
```

NOTE: *_obs_minimum* represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

3.4 Blowing Snow Frequency

On the ATL09 product is the parameter blowing snow layer thickness, *bsnow_h* (i.e., height above the surface in meters to the top of the blowing snow layer), at both high-rate (i.e., 25 Hz) and low-rate (i.e., 1 Hz). Originally stated in the ATBD: to create the blowing snow frequency, the low-rate (1 second) blowing snow height will be used. Previous releases of ATL16 and ATL17 only contained blowing snow frequency computed using the low-rate profile data. Now with this version two detection grids and two observation grids are collected to cover the polar regions (poleward of 60 degrees North and South). The low-rate profile data continues to be used for the production of both North and South polar low-rate blowing snow frequency. The additional high-rate profile data in the new high-rate detection and

observation grids is now used for the production of the new North and South polar high-rate blowing snow frequency gridded parameters.

In general, blowing snow height, *bsnow_h*, will only be > 0.0 (and not INVALID) when there is a detected blowing snow layer. Thus, when the latitude is poleward of 60N or 60S and whenever *bsnow_h* > 0.0 (and not INVALID), increment the grid box of the detection grid corresponding to the current latitude/longitude by one (1). If blowing snow confidence, *bsnow_con* is greater than or equal to -2 (but not INVALID), then increment the observation grid box of the current location by one (1). If *bsnow_con* is less than -2, it indicates that the surface was not detected. In this case do not consider it an observation and thus do not increment the observation grid (denominator). NOTE: the input parameters *bsnow_h* () and *bsnow_con* () will contain INVALID values in the profile observations. Therefore, INVALID input profile observation exception is required for these parameters.

With the requirement to produce both low-rate and high-rate blowing snow frequency as gridded parameters ("npolar_lorate_blowing_snow_freq", "spolar_lorate_blowing_snow_freq", "npolar_hirate_blowing_snow_freq", and "spolar_hirate_blowing_snow_freq"), inputs and outputs must be discriminated into low-rate (lorate_) and high-rate (hirate_) input sources and output destinations.

Typically for the northern hemisphere or the southern hemisphere, the low-rate blowing snow profile data is processed as follows:

the pseudocode below represents the conditional logic for incrementing the "*low-rate blowing snow detection grid*", i.e., the numerator grid, based on the filtered and accepted 1 Hz (low-rate) profile observations ():
for every 1 Hz profile occurrence of *lorate_bsnow_h* () ≠ INVALID 　　for *lorate_bsnow_h* () > 0.0 　　　　low-rate blowing snow detection grid (i,j) = low-rate blowing snow detection grid (i,j) + 1
a low-rate blowing snow layer has been detected
the pseudocode below represents the conditional logic for incrementing the "*low-rate blowing snow observation grid*", i.e., the denominator grid, based on the filtered and accepted 1 Hz (low-rate) profile observations ():
for every 1 Hz profile occurrence of *lorate_bsnow_con* () ≠ INVALID 　　for *lorate_bsnow_con* () => -2 　　　　low-rate blowing snow observation grid (i,j) = low-rate blowing snow observation grid (i,j) + 1

Similarly, typical for the northern hemisphere or the southern hemisphere, the high-rate blowing snow profile data is processed as follows:

the pseudocode below represents the conditional logic for incrementing the "*high-rate blowing snow detection grid*", i.e., the numerator grid, based on the filtered and accepted 25 Hz (high-rate) profile observations ():
for every 25 Hz profile occurrence of *hirate_bsnow_h* () ≠ INVALID 　　for *hirate_bsnow_h* () > 0.0 　　　　high-rate blowing snow detection grid (i,j) = high-rate blowing snow detection grid (i,j) + 1
a high-rate blowing snow layer has been detected

the pseudocode below represents the conditional logic for incrementing the "*high-rate blowing snow observation grid*", i.e., the denominator grid, based on the filtered and accepted 25 Hz (high-rate) profile observations ():

for every 25 Hz profile occurrence of *hirate_bsnow_con* () ≠ INVALID
    for *hirate_bsnow_con* () => -2
        high-rate blowing snow observation grid (i,j) = high-rate blowing snow observation grid (i,j) + 1

After all ATL09 files for the period in question have been processed in this way, the blowing snow frequency grid is obtained by dividing the detection grid by the observation grid (where the observation count equals or exceeds the product observation count minimum), and then multiplying by 100 to obtain percent. For cases where the number of observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the blowing snow frequency to INVALID.

Note that blowing snow frequency is the only parameter reported with units of percent.

For the northern hemisphere or the southern hemisphere, the low-rate blowing snow frequency gridded parameter is obtained as follows:

the pseudocode below represents the conditional logic for calculating the "*low-rate blowing snow frequency polar grid*" in percent by division of the "*low-rate blowing snow detection grid*", i.e., the numerator grid, by the "*low-rate blowing snow observation grid*", i.e., the denominator grid, then multiplying by 100, for either the weekly or the monthly atmosphere gridded data product:
for low-rate blowing snow observation grid (i,j) => *_obs_minimum*   low-rate blowing snow frequency polar grid (i,j) = $\dfrac{\text{low-rate blowing snow detection grid (i,j)}}{\text{low-rate blowing snow observation grid (i,j)}}$ X 100 else   low-rate blowing snow frequency polar grid (i,j) = INVALID
NOTE: *_obs_minimum* represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

For the northern hemisphere or the southern hemisphere, the high-rate blowing snow frequency gridded parameter is obtained as follows:

the pseudocode below represents the conditional logic for calculating the "*high-rate blowing snow frequency polar grid*" in percent by division of the "*high-rate blowing snow detection grid*", i.e., the numerator grid, by the "*high-rate blowing snow observation grid*", i.e., the denominator grid, then multiplying by 100, for either the weekly or the monthly atmosphere gridded data product:
for high-rate blowing snow observation grid (i,j) => *_obs_minimum*   high-rate blowing snow frequency polar grid (i,j) = $\dfrac{\text{high-rate blowing snow detection grid (i,j)}}{\text{high-rate blowing snow observation grid (i,j)}}$ X 100 else   high-rate blowing snow frequency polar grid (i,j) = INVALID
NOTE: *_obs_minimum* represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

3.5 Apparent Surface Reflectivity (ASR)

Apparent Surface Reflectivity (ASR) represents the true surface reflectivity modified by the two-way atmospheric transmission. It will generally be a number between 0 and 1. ASR is related to the ratio of the received energy to the transmitted energy and assumes a Lambertian surface reflectance. North and South polar grids and a global grid are established at the longitude and latitude grid size resolution and the dimensions for the weekly product, and for the monthly product, according to values contained in Table 2. The parameter *apparent_surf_reflec* on ATL09 will have a value of 0.0 unless there was a signal detected from the surface (i.e., correspondingly, *surface_sig* > 0.0). When the latitude is poleward of 60N or 60S and the parameter *apparent_surf_reflec* is greater than 0.0, it (i.e., *apparent_surf_reflec*) is added to the ASR (summation) grid box at the current location and the corresponding ASR observation grid box is incremented. If the ASR is equal to 0.0, do nothing. NOTE: the input parameters *apparent_surf_reflec* () and *surface_sig* () do not contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required.

For the global grid, and typically for the northern hemisphere or the southern hemisphere:

the pseudocode below represents the logic for selected accumulation of the "*ASR (summation) global grid*" and the "*ASR (summation) polar grid*", i.e., the numerator grids, and for selected increment of the corresponding "*global ASR observation grid*" and "*polar ASR observation grid*", i.e., the denominator grids, based on the filtered and accepted 25 Hz (high-rate) profile observations ():

for 25 Hz profile *apparent_surf_reflec* () > 0.0
    ASR (summation) global grid (i,j) = ASR (summation) global grid (i,j) + *apparent_surf_reflec* ()
    ASR (summation) polar grid (i,j) = ASR (summation) polar grid (i,j) + *apparent_surf_reflec* ()
    global ASR observation grid (i,j) = global ASR observation grid (i,j) + 1
    polar ASR observation grid (i,j) = polar ASR observation grid (i,j) + 1

After the period in question has been processed, the ASR grid is divided by the observation grid to get the average ASR grid ("global_asr", "npolar_asr", and "spolar_asr"). For cases where the number of observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the ASR to INVALID. For the global grid, and typically for the northern hemisphere or the southern hemisphere:

the pseudocode below represents the conditional logic for calculating the "*average ASR global grid*" and the "*average ASR polar grid*" by respective division of the "*ASR (summation) global grid*" and "*ASR (summation) polar grid*", i.e., the numerator grids, by the "*global ASR observation grid*" and "*polar ASR observation grid*", i.e., the denominator grids, for either the weekly or the monthly atmosphere gridded data product:
for total observation grid (i,j) => **_obs_minimum*

$$\text{average ASR global grid (i,j)} = \frac{\text{ASR (summation) global grid (i,j)}}{\text{global observation grid (i,j)}}$$

$$\text{average ASR polar grid (i,j)} = \frac{\text{ASR (summation) polar grid (i,j)}}{\text{polar observation grid (i,j)}}$$

```
    else
        average ASR global grid (i,j)  =  INVALID
        average ASR polar grid (i,j)  =  INVALID
```

NOTE: *_obs_minimum represents either *weekly_obs_minimum* or *monthly_obs_minimum* based on product

3.6 Ground Detection Frequency

For ground detection frequency ("global_grnd_detect", "npolar_grnd_detect", and "spolar_grnd_detect"), the ATL09 high-rate parameter *surface_sig* (i.e., surface signal count, the number of photons in the surface bin) should be used. This will be 0.0 unless the surface signal was detected. North and South Polar grids and a global grid are set up as in Section 3.5 above, and when *surface_sig* is > 0.0, the surface signal detection grid box at the current location is incremented. The corresponding observation grid box is incremented regardless of the value of *surface_sig*. NOTE: the input parameter *surface_sig* () <u>does not</u> contain INVALID values in the profile observations. Therefore, no INVALID input profile observation testing is required.

For the global grid and typically for the northern hemisphere or the southern hemisphere:

the pseudocode below represents the conditional logic for incrementing the "*surface signal detection global grid*" and the "*surface signal detection polar grid*", i.e., the numerator grids, for all 25 Hz (high-rate) profile observations ():

for 25 Hz profile *surface_sig* () > 0.0
    surface signal detection global grid (i,j) = surface signal detection global grid (i,j) + 1
    surface signal detection polar grid (i,j) = surface signal detection polar grid (i,j) + 1

the pseudocode below represents the logic for incrementing the "*global observation grid*" and "*polar observation grid*", i.e., the denominator grids, for all 25 Hz (high-rate) profile observations ():

for every 25 Hz profile
    global observation grid (i,j) = global observation grid (i,j) + 1
    polar observation grid (i,j) = polar observation grid (i,j) + 1

After the period in question has been processed, the ground detection frequency is calculated by dividing the surface signal grid by the observation grid for values of the observation grid equal to or exceeding the product observation minimum count value. For cases where the number of observations for a grid box is less than *week_obs_minimum* (ATL16) or *month_obs_minimum* (ATL17), set the ground detection frequency to INVALID.

the pseudocode below represents the conditional logic for calculating the "*ground detection frequency global grid*" and the "*ground detection frequency polar grid*" by respective division of the "*surface signal detection global grid*" and "*surface signal detection polar grid*", i.e., the numerator grids, by the "*global observation grid*" and "*polar observation grid*", i.e., the denominator grids, for either the weekly or the monthly atmosphere gridded data product:
for total observation grid (i,j) => *_obs_minimum$$\text{ground detection frequency global grid (i,j)} = \frac{\text{surface signal detection global grid (i,j)}}{\text{global observation grid (i,j)}}$$

$$\text{ground detection frequency polar grid (i,j)} \ = \ \frac{\text{surface signal detection polar grid (i,j)}}{\text{polar observation grid (i,j)}}$$

else

    ground detection frequency global grid (i,j) = INVALID

    ground detection frequency polar grid (i,j) = INVALID

NOTE: *_obs_minimum represents either weekly_obs_minimum or monthly_obs_minimum based on product

3.7 Images of Gridded Fields

Included on both products will be images of selected atmospheric variables. The global and polar atmosphere gridded parameters' grid images will overlay map images showing continental and country boundaries. Polar stereographic projection is used for the polar plots and equirectangular projection for the global images. The images can be either jpeg or png format. See the bottom of Table 5 for a list of images to be included on the products. The images have the same root name as the atmosphere gridded parameters with the added suffix "_img". For example, for the gridded parameter "global_cloud_frac" will be incorporated as the image "global_cloud_frac_img". NOTE that the list of images contained in Table 5 is not meant to be definitive. It is acceptable if images of other data fields are included.

NOTE: the image labels are included with the HDF5 product templates for the ATL16 and ATL17 products. These labels are embedded are part of the global (rectangular) projection images and the polar (stereographic) projection images in the weekly ATL16 or the monthly ATL17 atmosphere gridded data products. For the images listed in Table 5, the contents of the Description fields are the actual label character strings that are included in the product templates and will be applied to the generated gridded parameter global and polar projection images.

3.8 Minimum Number of Observations for Each Grid Box

In the computation of the various data fields, the data are divided by the number of observations in each grid box. For the ATBD Version 2.2a, we introduce two new control parameters called week_obs_minimum and month_obs_minimum. If the number of observations for a given grid box is less than week_obs_minimum for ATL16, then the value of that grid box is set to INVALID. It would be as if there were no observations at all for that grid box. If the number of observations is less than month_obs_minimum for ATL17, then the value of that grid box is set to INVALID. The nominal values for these parameters are: week_obs_minimum = 2 and month_obs_minimum = 4. These values are implemented within the code as constants and defaults. Control file execution overrides for these parameters will be available for replacement of these default values.

3.9 Observations Grids

For Version 2.1 of this ATBD the following five (5) observation grids were added to the products:

North Polar Blowing Snow Frequency – new parameter "npolar_bsnow_obs_grid"
South Polar Blowing Snow Frequency – new parameter "spolar_bsnow_obs_grid"
Global ASR – new parameter "asr_obs_grid"

Global Total Column Optical Depth - "tcod_obs_grid"
Global Cloud or Aerosol Fraction - "global_cloud_aerosol_obs_grid"

With this latest ATBD Version 3.1c DRAFT, the two existing (low-rate profile) polar blowing snow frequency observation count grids are expanded and renamed as a result of the addition of the high-rate profile polar blowing snow frequency observation count grids. Subsequently, the following four (4) polar blowing snow observation count grids replace the previous two (2) count grids:

North Polar Low-Rate Blowing Snow Frequency – new parameter "npolar_lorate_bsnow_obs_grid"
South Polar Low-Rate Blowing Snow Frequency – new parameter "spolar_lorate_bsnow_obs_grid"
North Polar High-Rate Blowing Snow Frequency – new parameter "npolar_hirate_bsnow_obs_grid"
South Polar High-Rate Blowing Snow Frequency – new parameter "spolar_hirate_bsnow_obs_grid"

NOTE: the parameters "npolar_bsnow_obs_grid" and "spolar_bsnow_obs_grid" included in the Version 2 ATL16/ATL17 products are now renamed to "npolar_lorate_bsnow_obs_grid" and "spolar_lorate_bsnow_obs_grid" observation grid parameters to clearly discriminate from the new high-rate profile data polar blowing snow frequency grid count parameters.

These observation grids are loaded from a selected set of "denominator grids" representing the logically filtered observation counter grids or the total observation grids collected in earlier sections above for the following parameters listed in Table 4 below:

Table 4. Atmosphere Gridded Products Observation Grid Parameters, Sources, Applicable Parameters

observation [count] grid parameter	Section	atmosphere gridded parameter algorithm source: count	applicable to atmosphere gridded parameters
global_cloud_aerosol_obs_grid (i,j)	3.1, 3.6	global cloud fraction: count of every 25 Hz profile observation	global_cloud_frac (i,j), global_aerosol_frac (i,j), global_grnd_detect (i,j)
tcod_obs_grid (i,j)	3.2	[global] total column optical depth: count of every valid 25 Hz profile apparent surface reflectance column optical depth [*column_od_asr* () > 0.0] over water [*column_od_asr_qf* () = 4] observation	global_column_od (i,j)
global_asr_obs_grid (i,j)	3.5	[global] apparent surface reflectance (ASR): count of every 25 Hz profile surface signal detected ASR [*apparent_surf_reflec* () > 0.0] observation	global_asr (i,j)
npolar_lorate_bsnow_obs_grid (i,j)	3.4	[north polar low-rate] blowing snow frequency: count of every valid 1 Hz blowing snow layer detected confidence [*bsnow_con* () >= -2] observation in the northern polar region	npolar_lorate_blowing_snow_freq (i,j)

observation [count] grid parameter	Section	atmosphere gridded parameter algorithm source: count	applicable to atmosphere gridded parameters
spolar_lorate_bsnow_obs_grid (i,j)	3.4	[south polar low-rate] blowing snow frequency: count of every valid 1 Hz blowing snow layer detected confidence [*bsnow_con* () >= -2] observation in the southern polar region	spolar_lorate_blowing_snow_freq (i,j)
npolar_hirate_bsnow_obs_grid (i,j)	3.4	[north polar high-rate] blowing snow frequency: count of every valid 25 Hz blowing snow layer detected confidence [*bsnow_con* () >= -2] observation in the northern polar region	npolar_hirate_blowing_snow_freq (i,j)
spolar_hirate_bsnow_obs_grid (i,j)	3.4	[south polar high-rate] blowing snow frequency: count of every valid 25 Hz blowing snow layer detected confidence [*bsnow_con* () >= -2] observation in the southern polar region	spolar_hirate_blowing_snow_freq (i,j)
npolar_cloud_obs_grid (i,j)	3.1, 3.3.1, 3.6	[north] polar total cloud fraction: count of every 25 Hz profile observation in the northern polar region	npolar_lowcloud_frac (i,j), npolar_midcloud_frac (i,j), npolar_highcloud_frac (i,j), npolar_totalcloud_frac (i,j), npolar_transcloud_frac (i,j), npolar_opaquecloud_frac (i,j), npolar_grnd_detect (i,j)
spolar_cloud_obs_grid (i,j)	3.1, 3.3.1, 3.6	[south] polar total cloud fraction: count of every 25 Hz profile observation in the southern polar region	spolar_lowcloud_frac (i,j), spolar_midcloud_frac (i,j), spolar_highcloud_frac (i,j), spolar_totalcloud_frac (i,j), spolar_transcloud_frac (i,j), spolar_opaquecloud_frac (i,j), spolar_grnd_detect (i,j)
npolar_asr_obs_grid (i,j)	3.5	[north polar] apparent surface reflectance (ASR): count of every 25 Hz profile surface signal detected ASR [*apparent_surf_reflec* () > 0.0] observation in the northern polar region	npolar_asr (i,j)
spolar_asr_obs_grid (i,j)	3.5	[south polar] apparent surface reflectance (ASR): count of every 25 Hz profile surface signal detected ASR [*apparent_surf_reflec* () > 0.0] observation in the southern polar region	spolar_asr (i,j)

3.10 Product Statistical Values

For each product gridded parameter for which an image is made, a set of statistical values of the data, consisting of the data minimum, maximum, mean, and standard deviation values, will be displayed on the grid image, and will be written to the atmosphere gridded product. The statistical values will be included on the image in the proximity of the image parameter label, centered below the label. For example, on the global cloud fraction image, a character string sub-label with the format "Min =

x.xxxxxx, Max = x.xxxxxx, Mean = x.xxxxxx, StdDev = x.xxxxxx" will be displayed below the image label: "Average Global Cloud Fraction" (centered below the label). The statistical values of the various data product gridded parameters identified in Table 6 are to be written to the product within the quality assessment group. The statistical values contained in the atmosphere gridded product quality_assessment/atmosphere group will be supplied to the image generation code to prepare the image statistical label. [NOTE: example graphics of a typical global (rectangular projection) image and a polar (polar stereographic projection) image with the statistical values label are included as Attachments A-1 and A-2 at the end of this ATBD.)

4.0 Smoothing of Images

For Version 2.0 of this ATBD, two control parameters are introduced, called *smooth_grid* and *center_weight*. If the control parameter *smooth_grid* is equal to 1, then it means to apply the smoothing algorithm below to either the weekly product (ATL16) images, or the monthly product (ATL17) images, based on the product being generated by the PGE. NOTE that the smoothing algorithm is to be applied only to the data to produce the images and not to the gridded data fields that are written to the products. The nominal [default] value of *smooth_grid* is 1. The *center_weight* control parameter is a real value from 0.0 to 1.0 with a nominal [default] value of 0.6. NOTE that the *center_weight* control parameter is <u>not</u> active when image smoothing is deselected (overridden with *smooth_grid* = 0). These control parameter values are installed in the program code as constants [defaults], and may be replaced by override statements included in the execution processing control file. The algorithm below shall be used in the smoothing of the gridded data fields.

Smoothing shall be applied in the following manner. Let imax be the number of longitude points in a given grid and jmax the number of latitude points. Let the addressing indices go from 1 to imax (i.e., not 0 to imax-1) and let Grid represent a gridded data parameter. The source gridded data may contain INVALID data.

```
model code represents the logic for implementing the atmosphere gridded image data smoothing algorithm

   smooth_grid(*,*) = INVALID

   for j= 2, jmax-1 do begin
      for i= 2, imax-1 do begin
          cnt = 0.0
          sum = 0.0
          for ii= i-1, i+1 do begin
              for jj= j-1, j+1 do begin
                  if (jj ne j or ii ne i) then begin
                      if (grid (ii,jj) ne INVALID) then begin
                          cnt++
                          sum = sum + Grid (ii,jj)

                      endif
                  endif
              endfor
```

```
        endfor
        avg = 0.0
        if (cnt gt 0.0) then avg = sum / cnt
        pix = 0.0
        weight = 0.0
        if (grid (i,j) ne INVALID) then begin
            weight = center_weight
            pix = Grid (i,j)*weight
        endif
        spix = avg * (1.0 – weight) + pix
        if (spix ne 0.0) then smooth_grid (i,j) = spix
    endfor
  endfor

  for i= 1, imax do begin
    if (Grid (i,1) ne INVALID and Grid (i,2) ne INVALID) then &
        smooth_grid (i,1) = (Grid (i,1) + Grid (i,2)) / 2.0
    if (Grid (i,jmax-1) ne INVALID and Grid (i,jmax) ne INVALID) then &
        smooth_grid (i,jmax) = (Grid (i,jmax-1) + Grid (i,jmax)) / 2.0
  endfor
  for j= 1, jmax do begin
    if (Grid (1,j) ne INVALID and Grid (2,j) ne INVALID) then  &
        smooth_grid (1,j) = (Grid (1,j) + Grid (2,j)) / 2.0
    if (Grid (imax,j) ne INVALID and Grid (imax-1,j) ne INVALID) then &
        smooth_grid (imax,j) = (Grid (imax-1,j) + Grid (imax,j)) / 2.0
  endfor
```

NOTES: the above smoothing algorithm code is to be functionally implemented in the source code for the graphics image production for the ATL16/ATL17 products. If the smoothing algorithm for images is specified, the product parameter grid array data is smoothed locally within the imaging code using internal buffered data– and the source gridded parameter data in the product is not modified.

5.0 Product Formats

As mentioned in Section 1.0, ATL16 and ATL17 contain the same atmosphere gridded variables. The only difference between the products is the resolution of the grids, the resolution of the linear latitude and longitude arrays, and the frequency that they will be produced. Tables 2 and 3, also in Section 1.0, provide the global and polar grid sizes and the linear array sizes for the weekly-produced ATL16 and the monthly-produced ATL17 atmosphere gridded products represented in Table 5. Table 6 lists the added Section 3.10 product statistical values as a separate table. The statistical parameters are common to both the ATL16 and ATL17 products.

It is noted for the product images listed in Table 5 that the Description column contains the actual labels to be applied to the embedded graphic for each imaged parameter.

Table 5. Gridded Products List of Gridded and Linear Parameters, Ancillary Data, and Images

Group: /					
Parameter	Type	ATL16 Dim.	ATL17 Dim.	Units	Description
start_time	double precision	(1)	(1)	seconds since 2018-01-01	start time/date of data used to make product
end_time	double precision	(1)	(1)	seconds since 2018-01-01	end time/date of data used to make product
data_qa_flag	integer	(1)	(1)		TBD
npolar_grid_lat	float	(30)	(60)	degrees	latitudes of north polar grid
spolar_grid_lat	float	(30)	(60)	degrees	latitudes of south polar grid
npolar_grid_lon	float	(120)	(240)	degrees	longitudes of north polar grid
spolar_grid_lon	float	(120)	(240)	degrees	longitudes of south polar grid
global_grid_lat	float	(60)	(180)	degrees	latitudes of global grid
global_grid_lon	float	(120)	(360)	degrees	longitudes of global grid
npolar_lorate_bsnow _obs_grid	float	(120,30)	(240,60)	N/A	the number of low-rate blowing snow confidence observations used in the computation of low-rate blowing snow frequency for the Arctic
spolar_lorate_bsnow _obs_grid	float	(120,30)	(240,60)	N/A	the number of low-rate blowing snow confidence observations used in the computation of low-rate blowing snow frequency for the Antarctic
npolar_hirate_bsnow _obs_grid	float	(120,30)	(240,60)	N/A	the number of high-rate blowing snow confidence observations used in the computation of high-rate blowing snow frequency for the Arctic
spolar_hirate_bsnow _obs_grid	float	(120,30)	(240,60)	N/A	the number of high-rate blowing snow confidence observations used in the computation of high-rate blowing snow frequency for the Antarctic

Group: /					
Parameter	Type	ATL16 Dim.	ATL17 Dim.	Units	Description
global_asr_obs_grid	float	(120,60)	(360,180)	N/A	the number of observations used to compute the average global apparent surface reflectance (ASR)
tcod_obs_grid	float	(120,60)	(360,180)	N/A	the number of observations used to compute the average global total column optical depth over water
global_cloud_aerosol _obs_grid	float	(120,60)	(360,180)	N/A	the number of total observations available to compute the global cloud fraction and the global aerosol fraction
global_cloud_frac	float	(120,60)	(360,180)	fraction	global cloud fraction
global_aerosol_frac	float	(120,60)	(360,180)	fraction	global aerosol fraction
global_column_od	float	(120,60)	(360,180)	unitless	global (over ocean) total column optical depth
npolar_lowcloud_frac	float	(120,30)	(240,60)	fraction	north polar low (<= 4 km) cloud fraction
spolar_lowcloud_frac	float	(120,30)	(240,60)	fraction	south polar low (<= 4 km) cloud fraction
npolar_midcloud_frac	float	(120,30)	(240,60)	fraction	north polar mid (> 4 km and <= 8 km) cloud fraction
spolar_midcloud_frac	float	(120,30)	(240,60)	fraction	south polar mid (> 4 km and <= 8 km) cloud fraction
npolar_highcloud_frac	float	(120,30)	(240,60)	fraction	north polar high (> 8 km) cloud fraction
spolar_highcloud_frac	float	(120,30)	(240,60)	fraction	south polar high (> 8 km) cloud fraction
npolar_totalcloud_frac	float	(120,30)	(240,60)	fraction	north polar total cloud fraction
spolar_totalcloud_frac	float	(120,30)	(240,60)	fraction	south polar total cloud fraction
npolar_transcloud_frac	float	(120,30)	(240,60)	fraction	north polar transmissive cloud fraction
spolar_transcloud_frac	float	(120,30)	(240,60)	fraction	south polar transmissive cloud fraction
npolar_opaquecloud _frac	float	(120,30)	(240,60)	fraction	north polar opaque cloud fraction
spolar_opaquecloud _frac	float	(120,30)	(240,60)	fraction	south polar opaque cloud fraction

Group: /					
Parameter	Type	ATL16 Dim.	ATL17 Dim.	Units	Description
npolar_lorate_blowing _snow_freq	float	(120,30)	(240,60)	percent	low-rate blowing snow frequency for the northern hemisphere polar region
spolar_lorate_blowing _snow_freq	float	(120,30)	(240,60)	percent	low-rate blowing snow frequency for the southern hemisphere polar region
npolar_hirate_blowing _snow_freq	float	(120,30)	(240,60)	percent	high-rate blowing snow frequency for the northern hemisphere polar region
spolar_hirate_blowing _snow_freq	float	(120,30)	(240,60)	percent	high-rate blowing snow frequency for the southern hemisphere polar region
npolar_asr	float	(120,30)	(240,60)	0 - 1	north polar apparent surface reflectance
spolar_asr	float	(120,30)	(240,60)	0 - 1	south polar apparent surface reflectance
global_asr	float	(120,60)	(360,180)	0 - 1	global apparent surface reflectance
npolar_grnd_detect	float	(120,30)	(240,60)	fraction	north polar ground detection frequency
spolar_grnd_detect	float	(120,30)	(240,60)	fraction	south polar ground detection frequency
global_grnd_detect	float	(120,60)	(360,180)	fraction	global ground detection frequency
npolar_totalcloud_frac _img	image			fraction	North Polar Total Cloud Fraction
spolar_totalcloud_frac _img	image			fraction	South Polar Total Cloud Fraction
global_cloud_frac_img	image			fraction	Global Cloud Fraction
global_column_od _img	image			0 - 1.5	Global (Over Water) Total Column Optical Depth (0-1.5)
npolar_grnd_detect _img	image			fraction	North Polar Ground Detection Frequency (fraction)
spolar_grnd_detect _img	image			fraction	South Polar Ground Detection Frequency (fraction)
npolar_lorate_blowing _snow_freq_img	image			percent	North Polar Low-Rate Blowing Snow Frequency (percent)
spolar_lorate_blowing _snow_freq_img	image			percent	South Polar Low-Rate Blowing Snow Frequency (percent)

Group: /					
Parameter	Type	ATL16 Dim.	ATL17 Dim.	Units	Description
npolar_hirate_blowing _snow_freq_img	image			percent	North Polar High-Rate Blowing Snow Frequency (percent)
spolar_hirate_blowing _snow_freq_img	image			percent	South Polar High-Rate Blowing Snow Frequency (percent)
npolar_asr_img	image			0 - 1	North Polar Apparent Surface Reflectance (0-1)
spolar_asr_img	image			0 - 1	South Polar Apparent Surface Reflectance (0-1)
global_asr_img	image			0 - 1	Global Apparent Surface Reflectance (0-1)
global_aerosol_frac _img	image			fraction	Global Aerosol Fraction
npolar_lowcloud_frac _img	image			fraction	North Polar Low Cloud Fraction (<= 4km)
spolar_lowcloud_frac _img	image			fraction	South Polar Low Cloud Fraction (<= 4km)
npolar_midcloud_frac _img	image			fraction	North Polar Mid Cloud Fraction (> 4km and <= 8km)
spolar_midcloud_frac _img	image			fraction	South Polar Mid Cloud Fraction (> 4km and <= 8km)
npolar_highcloud_frac _img	image			fraction	North Polar High Cloud Fraction (> 8km)
spolar_highcloud_frac _img	image			fraction	South Polar High Cloud Fraction (> 8km)
npolar_transcloud_frac _img	image			fraction	North Polar Transmissive Cloud Fraction
spolar_transcloud_frac _img	image			fraction	South Polar Transmissive Cloud Fraction
npolar_opaquecloud _frac_img	image			fraction	North Polar Opaque Cloud Fraction
spolar_opaquecloud _frac_img	image			fraction	South Polar Opaque Cloud Fraction
global_grnd_detect _img	image			fraction	Global Ground Detection Frequency (fraction)

NOTE: for the images the Description field contains the label for the projection graphic.

Table 6. Gridded Products List of Ancillary Control Data

Group: /ancillary_data/atmosphere					
Parameter	Type	ATL16 Dim.	ATL17 Dim.	Units	Description
data_type_flag	integer	(1)	(1)	0, 1	tells whether night only data was used to make product. 0=no, 1=yes [default = 0]
polar_grid_lon_scale	float	(1)	(1)	degrees	polar grid projection cell longitude resolution (size) [defaults: ATL16 = 3.0, ATL17 = 1.5]
polar_grid_lat_scale	float	(1)	(1)	degrees	polar grid projection cell latitude resolution (size) [defaults: ATL16 = 1.0, ATL17 = 0.5]
global_grid_lon_scale	float	(1)	(1)	degrees	global grid projection cell longitude resolution (size) [defaults: ATL16 = 3.0, ATL17 = 1.0]
global_grid_lat_scale	float	(1)	(1)	degrees	global grid projection cell latitude resolution (size) [defaults: ATL16 = 3.0, ATL17 = 1.0]
obs_minimum	integer	(1)	(1)	N/A	minimum acceptable selected observation count from control constant [defaults: ATL16 = 2, ATL17 = 4]
smooth_grid	integer	(1)	(1)	0, 1	use smoothed grid data to generate parameter grid images: 0=generate images without smoothing, 1=generate images with smoothing applied [default = 1]
center_weight	float	(1)	(1)	N/A	weight factor used to scale each cell in the smoothed image production [default = 0.6]

NOTES: The values indicated in this document are listed as control defaults above; execution overrides are provided for replacement of these control parameters within the production environment. The parameters "*global_grid_lon_scale*" and "*polar_grid_lon_scale*" now replace the Version 2 ATL16/ATL17 parameter "*lon_scale*". Similarly, the parameters "*global_grid_lat_scale*" and "*polar_grid_lat_scale*" now replace the Version 2 ATL16/ATL17 parameter "*lat_scale*".

Table 7. Gridded Products List of Statistical Parameters

Group: /quality_assessment/atmosphere			
Parameter	Type	Units	Description
global_cloud_frac_min	float	fraction	global cloud fraction minimum
global_cloud_frac_max	float	fraction	global cloud fraction maximum
global_cloud_frac_mean	float	fraction	global cloud fraction mean
global_cloud_frac_sdev	float	fraction	global cloud fraction standard deviation
global_aerosol_frac_min	float	fraction	global aerosol fraction minimum
global_aerosol_frac_max	float	fraction	global aerosol fraction maximum
global_aerosol_frac_mean	float	fraction	global aerosol fraction mean
global_aerosol_frac_sdev	float	fraction	global aerosol fraction standard deviation
global_column_od_min	float	unitless	global (over water) total column optical depth minimum
global_column_od_max	float	unitless	global (over water) total column optical depth maximum
global_column_od_mean	float	unitless	global (over water) total column optical depth mean
global_column_od_sdev	float	unitless	global (over water) total column optical depth standard deviation
npolar_lowcloud_frac_min	float	fraction	north polar low (<= 4 km) cloud fraction minimum
npolar_lowcloud_frac_max	float	fraction	north polar low (<= 4 km) cloud fraction maximum
npolar_lowcloud_frac_mean	float	fraction	north polar low (<= 4 km) cloud fraction mean
npolar_lowcloud_frac_sdev	float	fraction	north polar low (<= 4 km) cloud fraction standard deviation
spolar_lowcloud_frac_min	float	fraction	south polar low (<= 4 km) cloud fraction minimum
spolar_lowcloud_frac_max	float	fraction	south polar low (<= 4 km) cloud fraction maximum
spolar_lowcloud_frac_mean	float	fraction	south polar low (<= 4 km) cloud fraction mean
spolar_lowcloud_frac_sdev	float	fraction	south polar low (<= 4 km) cloud fraction standard deviation
npolar_midcloud_frac_min	float	fraction	north polar mid (> 4 km and <= 8 km) cloud fraction minimum
npolar_midcloud_frac_max	float	fraction	north polar mid (> 4 km and <= 8 km) cloud fraction maximum
npolar_midcloud_frac_mean	float	fraction	north polar mid (> 4 km and <= 8 km) cloud fraction mean
npolar_midcloud_frac_sdev	float	fraction	north polar mid (> 4 km and <= 8 km) cloud fraction standard deviation

Group: /quality_assessment/atmosphere			
Parameter	Type	Units	Description
spolar_midcloud_frac_min	float	fraction	south polar mid (> 4 km and <= 8 km) cloud fraction minimum
spolar_midcloud_frac_max	float	fraction	south polar mid (> 4 km and <= 8 km) cloud fraction maximum
spolar_midcloud_frac_mean	float	fraction	south polar mid (> 4 km and <= 8 km) cloud fraction mean
spolar_midcloud_frac_sdev	float	fraction	south polar mid (> 4 km and <= 8 km) cloud fraction standard deviation
npolar_highcloud_frac_min	float	fraction	north polar high (> 8 km) cloud fraction minimum
npolar_highcloud_frac_max	float	fraction	north polar high (> 8 km) cloud fraction maximum
npolar_highcloud_frac_mean	float	fraction	north polar high (> 8 km) cloud fraction mean
npolar_highcloud_frac_sdev	float	fraction	north polar high (> 8 km) cloud fraction standard deviation
spolar_highcloud_frac_min	float	fraction	south polar high (> 8 km) cloud fraction minimum
spolar_highcloud_frac_max	float	fraction	south polar high (> 8 km) cloud fraction maximum
spolar_highcloud_frac_mean	float	fraction	south polar high (> 8 km) cloud fraction mean
spolar_highcloud_frac_sdev	float	fraction	south polar high (> 8 km) cloud fraction standard deviation
npolar_totalcloud_frac_min	float	fraction	north polar total cloud fraction minimum
npolar_totalcloud_frac_max	float	fraction	north polar total cloud fraction maximum
npolar_totalcloud_frac_mean	float	fraction	north polar total cloud fraction mean
npolar_totalcloud_frac_sdev	float	fraction	north polar total cloud fraction standard deviation
spolar_totalcloud_frac_min	float	fraction	south polar total cloud fraction minimum
spolar_totalcloud_frac_max	float	fraction	south polar total cloud fraction maximum
spolar_totalcloud_frac_mean	float	fraction	south polar total cloud fraction mean
spolar_totalcloud_frac_sdev	float	fraction	south polar total cloud fraction standard deviation
npolar_transcloud_frac_min	float	fraction	north polar transmissive cloud fraction minimum
npolar_transcloud_frac_max	float	fraction	north polar transmissive cloud fraction maximum

Group: /quality_assessment/atmosphere			
Parameter	Type	Units	Description
npolar_transcloud_frac_mean	float	fraction	north polar transmissive cloud fraction mean
npolar_transcloud_frac_sdev	float	fraction	north polar transmissive cloud fraction standard deviation
spolar_transcloud_frac_min	float	fraction	south polar transmissive cloud fraction minimum
spolar_transcloud_frac_max	float	fraction	south polar transmissive cloud fraction maximum
spolar_transcloud_frac_mean	float	fraction	south polar transmissive cloud fraction mean
spolar_transcloud_frac_sdev	float	fraction	south polar transmissive cloud fraction standard deviation
npolar_opaquecloud_frac_min	float	fraction	north polar opaque cloud fraction minimum
npolar_opaquecloud_frac_max	float	fraction	north polar opaque cloud fraction maximum
npolar_opaquecloud_frac_mean	float	fraction	north polar opaque cloud fraction mean
npolar_opaquecloud_frac_sdev	float	fraction	north polar opaque cloud fraction standard deviation
spolar_opaquecloud_frac_min	float	fraction	south polar opaque cloud fraction minimum
spolar_opaquecloud_frac_max	float	fraction	south polar opaque cloud fraction maximum
spolar_opaquecloud_frac_mean	float	fraction	south polar opaque cloud fraction mean
spolar_opaquecloud_frac_sdev	float	fraction	south polar opaque cloud fraction standard deviation
npolar_lorate_blowing_snow_freq_min	float	percent	low-rate blowing snow frequency for the northern hemisphere polar region minimum
npolar_lorate_blowing_snow_freq_max	float	percent	low-rate blowing snow frequency for the northern hemisphere polar region maximum
npolar_lorate_blowing_snow_freq_mean	float	percent	low-rate blowing snow frequency for the northern hemisphere polar region mean
npolar_lorate_blowing_snow_freq_sdev	float	percent	low-rate blowing snow frequency for the northern hemisphere polar region standard deviation
spolar_lorate_blowing_snow_freq_min	float	percent	low-rate blowing snow frequency for the southern hemisphere polar region minimum

Group: /quality_assessment/atmosphere			
Parameter	Type	Units	Description
spolar_lorate_blowing_snow_freq_max	float	percent	low-rate blowing snow frequency for the southern hemisphere polar region maximum
spolar_lorate_blowing_snow_freq_mean	float	percent	low-rate blowing snow frequency for the southern hemisphere polar region mean
spolar_lorate_blowing_snow_freq_sdev	float	percent	low-rate blowing snow frequency for the southern hemisphere polar region standard deviation
npolar_hirate_blowing_snow_freq_min	float	percent	high-rate blowing snow frequency for the northern hemisphere polar region minimum
npolar_hirate_blowing_snow_freq_max	float	percent	high-rate blowing snow frequency for the northern hemisphere polar region maximum
npolar_hirate_blowing_snow_freq_mean	float	percent	high-rate blowing snow frequency for the northern hemisphere polar region mean
npolar_hirate_blowing_snow_freq_sdev	float	percent	high-rate blowing snow frequency for the northern hemisphere polar region standard deviation
spolar_hirate_blowing_snow_freq_min	float	percent	high-rate blowing snow frequency for the southern hemisphere polar region minimum
spolar_hirate_blowing_snow_freq_max	float	percent	high-rate blowing snow frequency for the southern hemisphere polar region maximum
spolar_hirate_blowing_snow_freq_mean	float	percent	high-rate blowing snow frequency for the southern hemisphere polar region mean
spolar_hirate_blowing_snow_freq_sdev	float	percent	high-rate blowing snow frequency for the southern hemisphere polar region standard deviation
npolar_asr_min	float	0 - 1	north polar apparent surface reflectance minimum
npolar_asr_max	float	0 - 1	north polar apparent surface reflectance maximum
npolar_asr_mean	float	0 - 1	north polar apparent surface reflectance mean
npolar_asr_sdev	float	0 - 1	north polar apparent surface reflectance standard deviation
spolar_asr_min	float	0 - 1	south polar apparent surface reflectance minimum

Group: /quality_assessment/atmosphere			
Parameter	Type	Units	Description
spolar_asr_max	float	0 - 1	south polar apparent surface reflectance maximum
spolar_asr_mean	float	0 - 1	south polar apparent surface reflectance mean
spolar_asr_sdev	float	0 - 1	south polar apparent surface reflectance standard deviation
global_asr_min	float	0 - 1	global apparent surface reflectance minimum
global_asr_max	float	0 - 1	global apparent surface reflectance maximum
global_asr_mean	float	0 - 1	global apparent surface reflectance mean
global_asr_sdev	float	0 - 1	global apparent surface reflectance standard deviation
npolar_grnd_detect_min	float	fraction	north polar ground detection frequency minimum
npolar_grnd_detect_max	float	fraction	north polar ground detection frequency maximum
npolar_grnd_detect_mean	float	fraction	north polar ground detection frequency mean
npolar_grnd_detect_sdev	float	fraction	north polar ground detection frequency standard deviation
spolar_grnd_detect_min	float	fraction	south polar ground detection frequency minimum
spolar_grnd_detect_max	float	fraction	south polar ground detection frequency maximum
spolar_grnd_detect_mean	float	fraction	south polar ground detection frequency mean
spolar_grnd_detect_sdev	float	fraction	south polar ground detection frequency standard deviation
global_grnd_detect_min	float	fraction	global ground detection frequency minimum
global_grnd_detect_max	float	fraction	global ground detection frequency maximum
global_grnd_detect_mean	float	fraction	global ground detection frequency mean
global_grnd_detect_sdev	float	fraction	global ground detection frequency standard deviation

NOTE: the atmosphere gridded parameters statistical data will be located within the product
"/quality_assessment/atmosphere" group.

6.0 Product Production Considerations

List of ATBD Lead suggestions regarding the date/time span for production of atmosphere gridded data products:

- the monthly product will begin on the first day of the month;
- the monthly data product will end on the last day of the month;
- the first weekly data product within the month will begin on the first day of the month, end on the seventh day of the month, and contain seven days;
- the second weekly data product within the month will begin on the eighth day of the month, end on the fourteenth day of the month, and contain seven days;
- the third weekly data product within the month will begin on the fifteenth day of the month, end on the twenty-first day of the month, and contain seven days;
- the fourth weekly data product within the month will begin on the twenty-second day of the month, end on either the twenty-eighth, twenty-ninth, thirtieth, or thirty-first day of the month, and will contain either seven days, eight days, nine days, or ten days, respectively, depending on the calendar month and leap year.

The following tables supply the beginning and ending dates for the control file generation for production of monthly ATL17 and weekly ATL16 atmosphere gridded data products.

6.1 ATL17 Monthly Atmosphere Gridded Product Content Control

Monthly ATL17 Product File Content Control Information
(used to control the collection and specification of ATL09 files to compose the product)

Month	Beginning Date	Ending Date	Number of Days	Possible Number of Files (RGTs)
January	January 01	January 31	31	474
February	February 01	February 28	28	428
February (leap year)	February 01	February 29	29	443
March	March 01	March 31	31	474
April	April 01	April 30	30	459
May	May 01	May 31	31	474
June	June 01	June 30	30	459
July	July 01	July 31	31	474
August	August 01	August 31	31	474
September	September 01	September 30	30	459
October	October 01	October 31	31	474
November	November 01	November 30	30	459
December	December 01	December 31	31	474

Table 8. Monthly ATL17 Data Product ATL09 File Composition by Month

6.2 ATL16 Weekly Atmosphere Gridded Product Content Control

Weekly ATL16 Product File Content Control Information
(used to control the collection and specification of ATL09 files to compose the product)

Month	Week	Beginning Date	Ending Date	Number of Days	Possible Number of Files (RGTs)
January	01	January 01	January 07	07	107
January	02	January 08	January 14	07	107
January	03	January 15	January 21	07	107
January	04	January 22	January 31	10	153
February	01	February 01	February 07	07	107
February	02	February 08	February 14	07	107
February	03	February 15	February 21	07	107
February	04	February 22	February 28	07	107
February (leap year)	04	February 22	February 29	08	123
March	01	March 01	March 07	07	107
March	02	March 08	March 14	07	107
March	03	March 15	March 21	07	107
March	04	March 22	March 31	10	153
April	01	April 01	April 07	07	107
April	02	April 08	April 14	07	107
April	03	April 15	April 21	07	107
April	04	April 22	April 30	09	138
May	01	May 01	May 07	07	107
May	02	May 08	May 14	07	107
May	03	May 15	May 21	07	107
May	04	May 22	May 31	10	153
June	01	June 01	June 07	07	107
June	02	June 08	June 14	07	107
June	03	June 15	June 21	07	107
June	04	June 22	June 30	09	138
July	01	July 01	July 07	07	107
July	02	July 08	July 14	07	107
July	03	July 15	July 21	07	107
July	04	July 22	July 31	10	153
August	01	August 01	August 07	07	107
August	02	August 08	August 14	07	107
August	03	August 15	August 21	07	107
August	04	August 22	August 31	10	153
September	01	September 01	September 07	07	107
September	02	September 08	September 14	07	107
September	03	September 15	September 21	07	107
September	04	September 22	September 30	09	138

Month	Week	Beginning Date	Ending Date	Number of Days	Possible Number of Files (RGTs)
October	01	October 01	October 07	07	107
October	02	October 08	October 14	07	107
October	03	October 15	October 21	07	107
October	04	October 22	October 31	10	153
November	01	November 01	November 07	07	107
November	02	November 08	November 14	07	107
November	03	November 15	November 21	07	107
November	04	November 22	November 30	09	138
December	01	December 01	December 07	07	107
December	02	December 08	December 14	07	107
December	03	December 15	December 21	07	107
December	04	December 22	December 31	10	153

Table 9. Weekly ATL16 Data Product ATL09 File Composition by Month and Week

A.0 Attachments

A.1 Attachment A-1: Exhibit Rectangular Image with Statistical Data Label

Attachment A-1 Exhibit "atlas_plot" Application ATL17 Product Python Code Generated Rectangular Projection Global Parameter Image with Added Grid Statistical Data Sub-Label.

Plotted: 2020-01-29T18:11:14
ATL17_20190301004639_09560201_001_01.h5
2019-03-01T00:46:39 - 2019-04-01T00:05:37

Global Cloud Fraction

Min = 0.000000, Max = 1.000000, Mean = 0.527927, StdDev = 0.278783
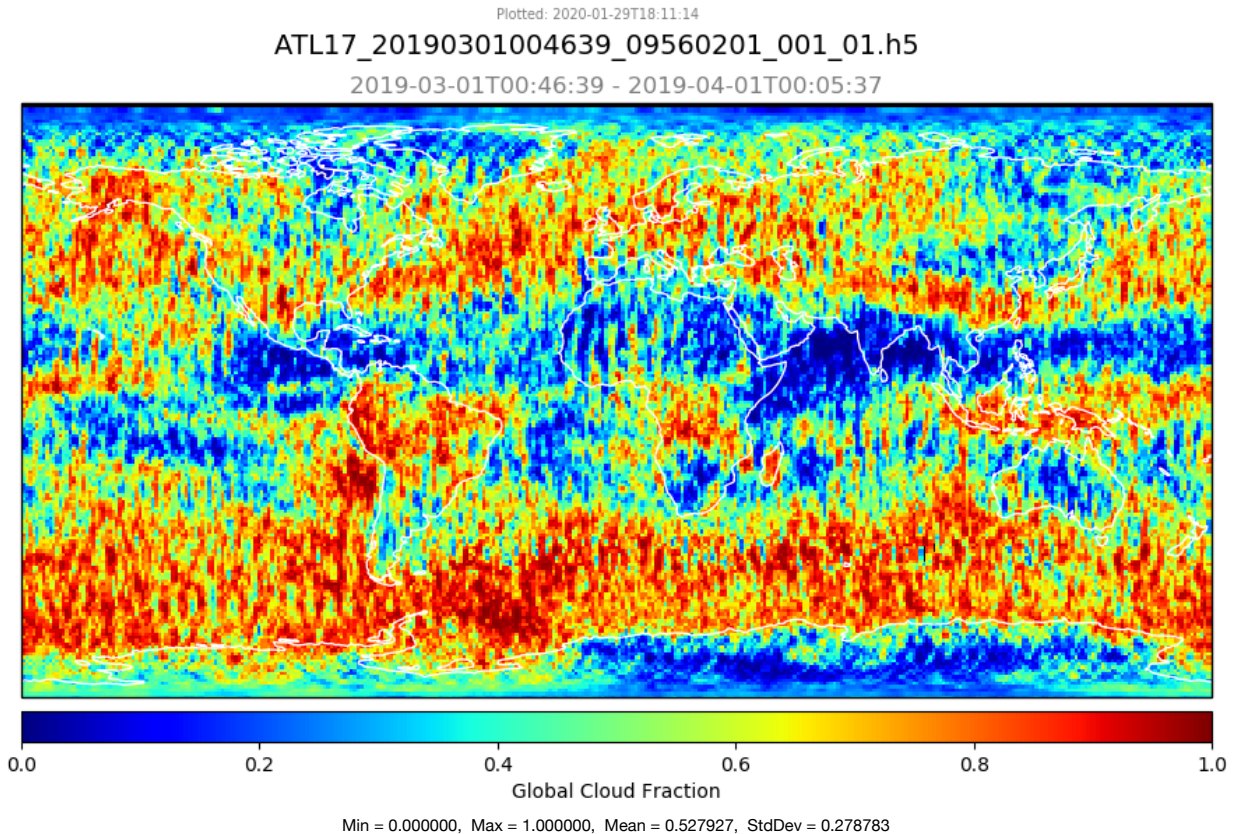
The graphic above presents the rectangular projection image of the Global Cloud Fraction parameter produced by the Python code application "atlas_plot.py" using the ATL16/ATL17 product specific "plot_atl16.py" Python code. The image extracted from the monthly ATL17 atmosphere gridded product for the month of March 2019 has been edited to apply the statistical data label showing the gridded data minimum, maximum, mean, and standard deviation values, positioned as a character text string sub-label

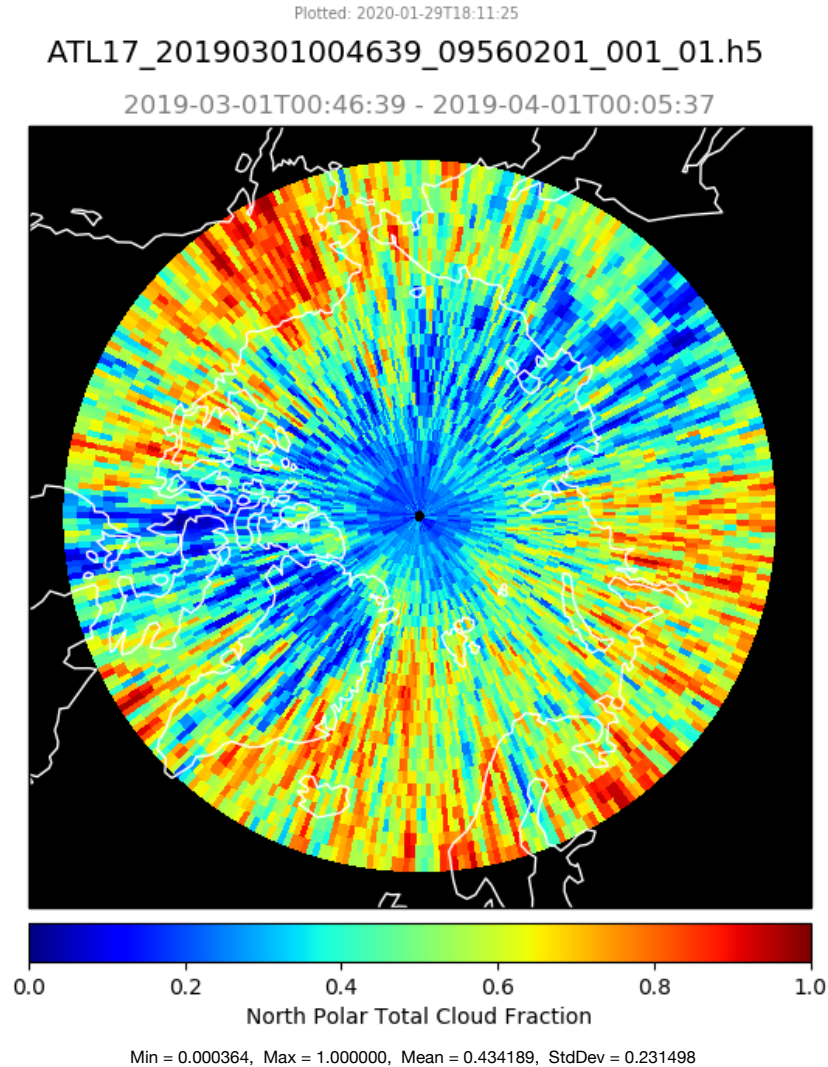Min = 0.000000, Max = 1.000000, Mean = 0.527927, StdDev = 0.278783

centered below the image parameter label

Global Cloud Fraction

The statistical date values for this example parameter image (and the other global and polar parameter images) will be obtained from the ATL17 product quality assessment data group by the image-generating Python code application. The basis for this image implementation is found in Section 3.10.

A.2 Attachment A-2: Exhibit Polar Image with Statistical Data Label

Attachment A-2 Exhibit "atlas_plot" Application ATL17 Product Python Code Generated Polar Stereographic Projection Polar Parameter Image with Added Grid Statistical Data Sub-Label.

Plotted: 2020-01-29T18:11:25

ATL17_20190301004639_09560201_001_01.h5

2019-03-01T00:46:39 - 2019-04-01T00:05:37

North Polar Total Cloud Fraction

Min = 0.000364, Max = 1.000000, Mean = 0.434189, StdDev = 0.231498

The graphic above presents the polar stereographic projection image of the North Polar Total Cloud Fraction parameter produced by the Python code application "atlas_plot.py" using the ATL16/ATL17 product specific "plot_atl16.py" Python code. The image extracted from the monthly ATL17 atmosphere gridded product for the month of March 2019 has been edited to apply the statistical data label showing the gridded data minimum, maximum, mean, and standard deviation values, positioned as a character text string sub-label

Min = 0.000364, Max = 1.000000, Mean = 0.434189, StdDev = 0.231498

centered below the image parameter label

North Polar Total Cloud Fraction

The statistical date values for this example parameter image (and the other global and polar parameter images) will be obtained from the ATL17 product quality assessment data group by the image-generating Python code application. The basis for this image implementation is found in Section 3.10.

NOTE that the above exhibit images are generated with "atlas_l3b_atm" version 1.1 PGE using the monthly polar grid cell size of 1 degree by 1 degree. The Version 1.2 PGE will generate the polar grid projection with a cell size of 1.5 degrees longitude by 0.5 degrees latitude.

A.3 Attachment A-3: Example Global Gridded Parameter Reference Layout

Example Global Gridded Parameter Reference Layout
Grid Cell Index Formula Application for Profile Data Gridding

Monthly Global Grid Reference Grid Cell

-180.0° => lon > -179.0°
-89.0° => lat > -88.0°

1 x 1 degree
monthly grid
grid cell

(0,1)

-179.0° => lon > -178.0°
-89.0° => lat > -88.0°

1 x 1 degree
monthly grid
grid cell

(1,1)

-180.0° => lon > -179.0°
-90.0° => lat > -89.0°

1 x 1 degree
monthly grid
reference
grid cell

(0,0)

-179.0° => lon > -178.0°
-90.0° => lat > -89.0°

1 x 1 degree
monthly grid
grid cell

(1,0)

-89.0°

latitude

-90.0°

-180.0°   longitude   -179.0°
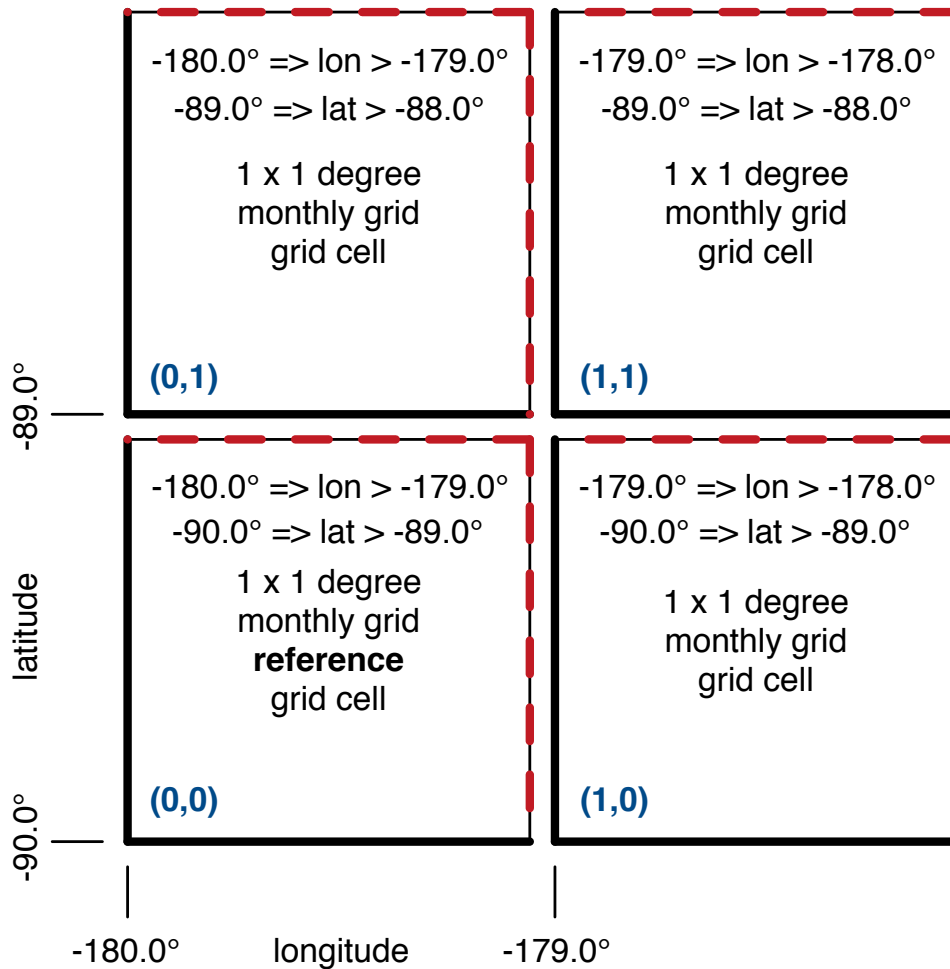
Global Grid Cell Index: (longitude index, latitude index)

───── closed boundary
─ ─ ─ open boundary

Reference index point: (0,0) = (-180,-90) = the <u>lower left corner</u>
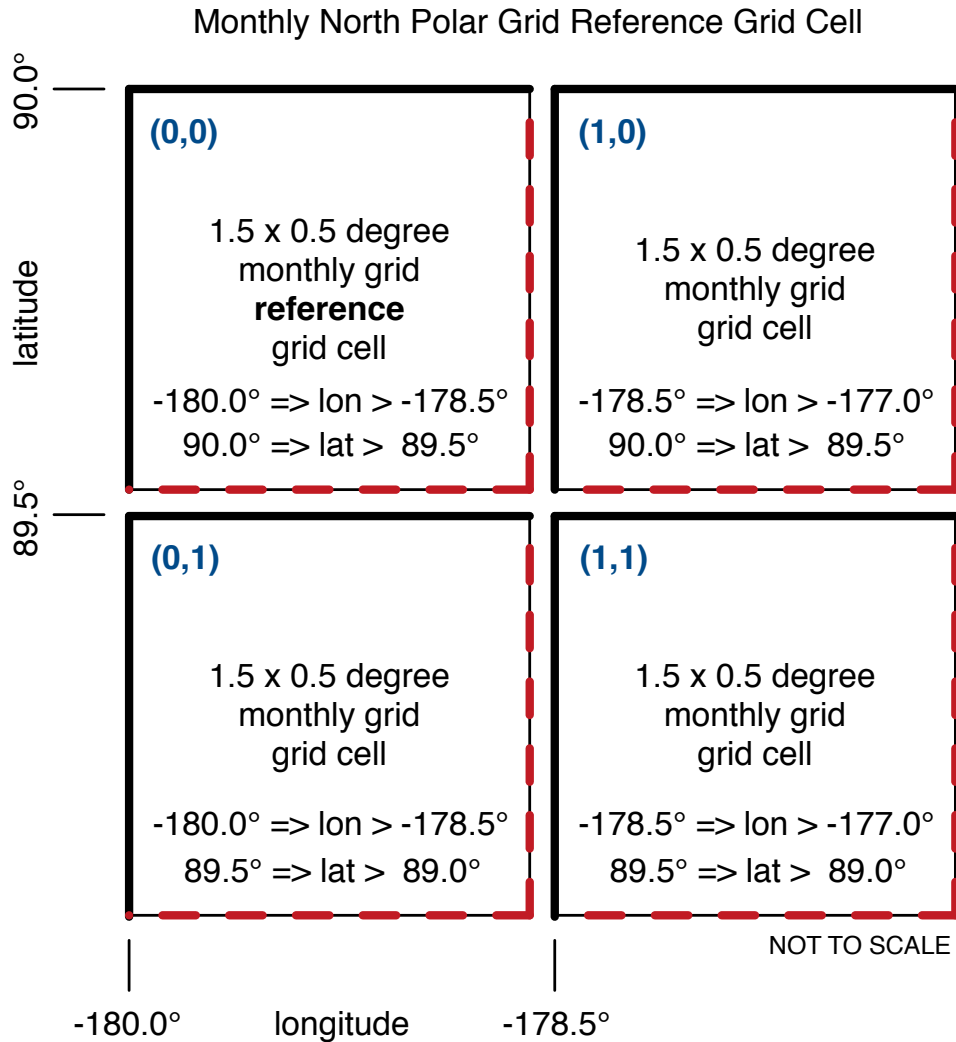Product: ATL17 – monthly gridded product (global parameters)
Grid size: global (rectangular projection): 1 degree longitude by 1 degree latitude

Attachment A-3 Graphical Image Illustrating Section 2.0 Global Grid Application and Index Computation for the ATL17 Monthly Gridded Atmosphere Product Parameter.

This graphic provides an example image to depict application of the Section 2.0 Global (rectangular projection) 1-degree longitude by 1-degree latitude grid cell size and indexing formula for the ATL17 monthly product grid cell mapping with open and closed boundaries indicated for the cells from the grid origin (reference) cell. For the global atmosphere gridded parameter array, the origin reference (longitude, latitude) = (i,j) index pair of (0,0) is equivalent to (-180°,-90°) and occurs at the lower left corner of the grid array.

A.4 Attachment A-4: Example North Polar Gridded Parameter Reference Layout

Example North Polar Gridded Parameter Reference Layout
Grid Cell Index Formula Application for Profile Data Gridding

Monthly North Polar Grid Reference Grid Cell

(0,0)

1.5 x 0.5 degree
monthly grid
reference
grid cell

-180.0° => lon > -178.5°
90.0° => lat > 89.5°

(1,0)

1.5 x 0.5 degree
monthly grid
grid cell

-178.5° => lon > -177.0°
90.0° => lat > 89.5°

(0,1)

1.5 x 0.5 degree
monthly grid
grid cell

-180.0° => lon > -178.5°
89.5° => lat > 89.0°

(1,1)

1.5 x 0.5 degree
monthly grid
grid cell

-178.5° => lon > -177.0°
89.5° => lat > 89.0°

NOT TO SCALE

latitude (axis): 90.0°, 89.5°

longitude (axis): -180.0°, -178.5°

North Polar Grid Cell Index: (longitude index, latitude index)

──── closed boundary
– – – open boundary

Reference index point: (0,0) = (-180,90) = the upper left corner
Product: ATL17 – monthly gridded product (polar parameters)
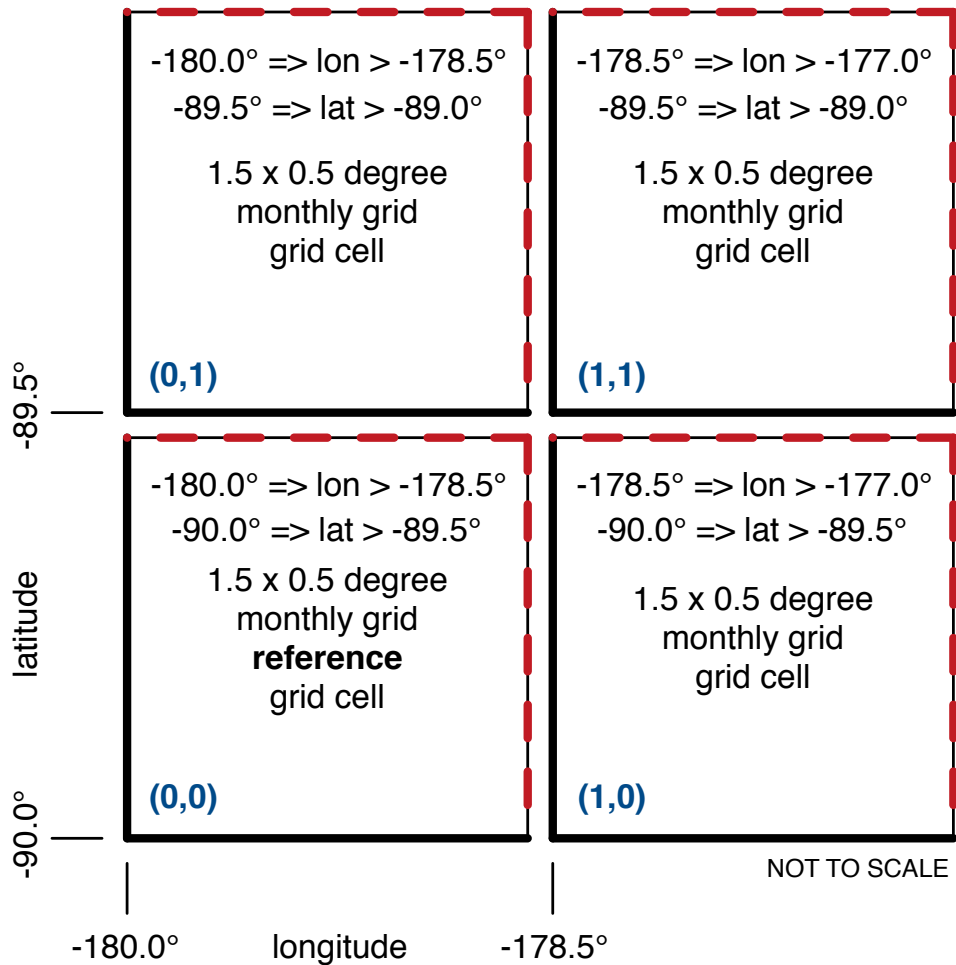Grid size: polar (polar stereographic): 1.5 degree longitude by 0.5 degree latitude

Attachment A-4 Graphical Image Illustrating Section 2.0 North Polar Grid Application and Index
Computation for the ATL17 Monthly Gridded Atmosphere Product Parameter

This graphic provides an example image to depict application of the Section 2.0 North Polar (polar stereographic projection) 1.5-degree longitude by 0.5-degree latitude grid cell size and indexing formula for the ATL17 monthly product grid cell mapping with open and closed boundaries indicated for the cells from the grid origin (reference) cell. For the North polar atmosphere gridded parameter array, the origin reference (longitude, latitude) = (i,j) index pair of (0,0) is equivalent to (-180°,90°) and occurs at the underline start upper left corner underline end of the grid array.

A.5 Attachment A-5: Example South Polar Gridded Parameter Reference Layout

Example South Polar Gridded Parameter Reference Layout
Grid Cell Index Formula Application for Profile Data Gridding

Monthly South Polar Grid Reference Grid Cell

-180.0° => lon > -178.5° -89.5° => lat > -89.0° 1.5 x 0.5 degree monthly grid grid cell **(0,1)**	-178.5° => lon > -177.0° -89.5° => lat > -89.0° 1.5 x 0.5 degree monthly grid grid cell **(1,1)**
-180.0° => lon > -178.5° -90.0° => lat > -89.5° 1.5 x 0.5 degree monthly grid **reference** grid cell **(0,0)**	-178.5° => lon > -177.0° -90.0° => lat > -89.5° 1.5 x 0.5 degree monthly grid grid cell **(1,0)**

latitude axis: -89.5°, -90.0°

longitude axis: -180.0°, longitude, -178.5°

NOT TO SCALE

South Polar Grid Cell Index: (longitude index, latitude index)

——— closed boundary
– – – open boundary

Reference index point: (0,0) = (-180,-90) = the <u>lower left corner</u>
Product: ATL17 – monthly gridded product (polar parameters)
Grid size: polar (polar stereographic): 1.5 degree longitude by 0.5 degree latitude

Attachment A-5 Graphical Image Illustrating Section 2.0 South Polar Grid Application and Index
Computation for the ATL17 Monthly Gridded Atmosphere Product Parameter

This graphic provides an example image to depict application of the Section 2.0 South Polar (polar stereographic projection) 1.5-degree longitude by 0.5 degrees latitude grid cell size and indexing formula for the ATL17 monthly product grid cell mapping with open and closed boundaries indicated for the cells from the grid origin (reference) cell. For the South polar atmosphere gridded parameter array, the origin reference (longitude, latitude) = (i,j) index pair of (0,0) is equivalent to (-180°,-90°) and occurs at the lower left corner of the grid array.