MODIS Atmosphere QA Plan

for Collection 005

Version 3.3
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based on previous version by
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Note 1: New and rewritten text for version 3.0 (changed from the previous version (2.2) of the QA Plan), along with Collection 005 updates to QA Flag assignments and definitions, are written in blue color (orange color for Appendix *Notes*) to help alert users to changes.

Note 2: Changes for version 3.1 are isolated in the Aerosol QA flags and are shown in red.

Note 3: Changes for version 3.3 are isolated in the Aerosol Cloud_Mask_QA and Aerosol Quality_Assurance_Land flags on pages 10 and 12 (shown in green).

1.0 Introduction

This document describes the QA (quality assessment or quality assurance) plan for all MODIS Atmosphere products. Topics covered include: quality evaluation approach and scenarios, Level 2 (L2) runtime QA structure and information content, types of L2 runtime QA flags, a primer on reading and interpreting L2 runtime QA flags, detail on how Level 2 (L2) confidence flags impact Level 3 (L3) product statistics, and finally a thorough breakdown of the structure and information content of L2 Runtime QA (in Appendix A).

Also included at the end of this document is information on Inventory and Archive Metadata structures that apply to both L2 and L3 products (in Appendix B and C).

It should be noted that within MODIS Atmosphere, the term "QA" is loosely defined to include a wide variety of flags that detail (1) confidence or quality, (2) retrieval processing path, (3) retrieval status or outcome, (4) retrieval method, (5) data or scene characteristics, and (6) metadata or ancillary input source.

Quality assessment is an important element in the sequential data reduction from Level 0 (L0) raw counts to Level 1B (L1B) calibrated radiance, and continually to Level 2 (L2) orbital swath granules and Level 3 (L3) global gridded products. Level 2 MODIS Atmosphere products, retrieved from MODIS instrument and ancillary data, are grouped into user-friendly Hierarchical Data Format (HDF) files based upon the general categories of aerosol, column water vapor, cloud, atmospheric profiles, cloud mask, and joint atmosphere. Level 3 Atmosphere products, which contain hundreds of 1°x1° global gridded parameters/statistics derived from the L2 products, are grouped into HDF files by temporal period: daily, eight-day, and monthly.

MODIS atmosphere products are grouped as follows (Earth Science Data Type (ESDT) names, used to identify each product by their HDF filename, are provided in parentheses):

Level 2 Products

- Aerosol (04_L2)
- Water Vapor (or Precipitable Water) (05_L2)
- Cloud Properties (06_L2)

- Atmospheric Profiles (07 _L2)
- Cloud Mask (35_L2)
- Joint Atmosphere (ATML2)

Level 3 Products

- Daily Global (08_D3)
- Eight-day Global (08_E3)
- Monthly Global (08_M3)

Each Level 2 atmospheric parameter is retrieved at a spatial resolution determined by the sensitivity of retrieval, not necessarily on a single field of view (FOV) basis. Resolutions typically range from 1x1 km to 10x10 km. Level 3 atmospheric parameters are computed at 1x1 degree spatial resolution.

There are two main types of flags described in this document: (1.) Runtime QA Flags and (2.) Metadata (either Inventory or Archive).

Runtime QA Flags (which are only computed and stored for Level 2 products) are designed to convey information on retrieval processing path, input data source, scene characteristics, and the estimated quality of the physical parameters retrieved. In addition, this broad group of flags also includes Cloud Mask QA flags (initially derived at 1×1 km resolution) that may be recomputed at the spatial resolution of the retrieval for the determination of cloudy and clear pixels, land surface type, sunglint, day/night, and snow/ice.

Metadata, on the other hand, are to report high-level granule characteristics and calculated statistics in the broad catagory of either Inventory or Archive Metadata. Inventory Metadata are searchable, whereas the Archive Metadata are for archival (documentation) only.

1.1 QA Approach

The (automatic) operational approach forms the key to the QA process of MODIS atmosphere products. This encompasses the Runtime QA flags and Metadata produced in each product as well as the operational procedures performed in real time at the GDAAC (Goddard DAAC) or MODAPS (MODIS Data Processing System).

The Runtime QA flags produced in Level 2 products are the central piece of this Quality Assurance (QA) Plan. They are designed not only to report success or failure of criteria being used in retrieval but also to estimate the data quality. These resolution-level QA flags provide much more detailed information and thus provide better information to produce Level 3 global products. The MODIS atmosphere Level 3 products are produced to include various statistical quantities (e.g., mean, standard deviation, histogram and regression). Theoretically, in evaluating the quality of the

retrieval, the quality of the inputs should also be considered. Thus, the Level 2 QA flags are to reflect only the product itself, with input sources flagged for later evaluation.

Introductory information on the type and structure of Runtime QA Flags, along with a primer on reading and interpreting QA Flags, can be found in Section 2. The key portion of this document is the detailed tabulation of Runtime QA Flags in Appendix A.

2.0 Level 2 Runtime QA Structure/Information Content

The quality of Level 2 product can be (1) inherited from the L1B radiances, or (2) associated with the retrieval process. The pixel-based L1B validity flags comprising information on dead and saturated detectors, calibration failure, etc., are examined by L2 algorithms for determination of the radiometric status of each pixel. This information can prevent further calculations from being performed if the "valid input data" criteria is not met by the given algorithm. The granule-level L1B QA metadata provides summary information for valid and saturated Earth view observations, and can be useful in screening a granule of data. Details about MODIS L1B QA flags can be found in the MODIS L1B QA plan. The structure and information content of MODIS Atmosphere runtime QA are detailed in the following sections.

It should be noted that Runtime QA flags are only found in Level 2 (L2) Atmosphere products. Level 3 (L3) Atmosphere products contain no Runtime QA flags (bit-string SDS's); however L2 runtime QA flags are used to compute (aggregate and weight) statistics in L3.

2.1 Types of Runtime QA Flags

The SDS run time QA flags are stored based upon product resolution. For convenience, the run time QA flags can be divided into three parts: (1) cloud mask flags, (2) product quality flags, and (3) retrieval processing flags.

Cloud Mask Flags are constructed using the Cloud Mask (35_L2). Typically they are based on the flags from the first byte only, however it may contain additional flags read from subsequent bytes. The first byte of the Cloud Mask is shown below:

Bits	Flag Name	Bit Values	Bit Value Definitions
0	Cloud Mask Status Flag	0	Undetermined
		1	Determined
1-2	Cloud Mask Cloudiness Flag	0	Confident Cloudy (or Fill, if Status Flag = 0)
		1	Probably Cloudy
		2	Probably Clear
		3	Confident Clear
3	Day / Night Flag	0	Night (or Fill, if Status Flag = 0)
		1	Day

4	Sunglint Flag	0 1	Yes (or Fill, if Status Flag = 0) No
5	Snow / Ice Flag	0 1	Yes (or Fill, if Status Flag = 0) No
6-7	Surface Type Flag	0 1 2 3	Ocean or Deep Lakes and Rivers (or Fill) Coast or Shallow Lakes and Rivers Desert Land

For L2 products at 1×1 km resolution, the first byte of the cloud mask will be written and stored, exactly as detailed above. For coarser resolution products (5x5 or 10x10 km), the information for each QA Flag will be determined by science team members based upon the retrieval method (it may be subsampled or averaged). To avoid duplication in products that are built from more than one retrieval algorithm, cloud mask QA flags will be stored only once in each product (HDF file). The only exception is the Cloud Product (06_L2), where the cloud mask QA flags will be stored at both 1×1 and 5×5 km resolutions.

Product Quality Flags are used to indicate the quality of each parameter retrieved at the product spatial resolution. The first bit indicates usefulness of the parameter, followed by two or three bits for the confidence level. Even though one can store a number from 0 to 7 (corresponding to 8 confidence levels) when three bits are allocated for the Confidence Flag, the Atmosphere L3 production processing software was develped to handle only 4 confidence levels (see table below), which can be adequately stored in only two bits. Usefulness Flags should always be read in tandum with Confidence Flags to differentiate between No Confidence but valid data vs. Fill (missing) data.

An example of the typical format for Product Quality Flags is shown below:

Flag Name	Bit Values	Bit Value Definitions	L3 QA-weighting
Example Parameter Usefulness Flag	0 1	Not useful Useful	Not used in L3 Used in L3
Example Parameter Confidence Flag	0 1 2 3	No Confidence (or Fill) Marginal Good Very Good	0x 1x 2x 3x

The MODIS Atmosphere L3 processing software makes use of the L2 Usefulness and Confidence flags by creating L3 QA-weighted mean and standard deviation statistics. The QA weighting is performed by weighting each L2 input pixel by its Confidence flag, so that non-fill *no confidence* data has a weight of 0x, *marginal* data has a weight of 1x, *good* data has a weight of 2x, and *very good* data has a weight of 3x in the statistical computation within the L3 one-degree grid box.

It should be noted that L3 "regular" (non QA-weighted) mean and standard

deviation statistics are not weighted by L2 Confidence flags and will **include** all *non-fill* L2 input pixels that have their Quality/Confidence flags set to 0; while the QA-weighted mean and standard deviation statistics will **exclude** these pixels. This technique allows for the creation of L3 (QA-weighted) statistics that can selectively exclude *no confidence* (or experimental) L2 results.

Finally, users should note that (in addition to regular simple statistics) L2 QA Confidence flags are also ignored in the L3 computation of pixel count, histogram, joint histogram, and regression statistics.

Retrieval Processing Flags are used for miscellaneous purposes. The bit length and information content are determined by the responsible science team member. In general, it may contain:

- Physical, algorithm, climatological constraints
- Atmospheric correction (Rayleigh scattering, gaseous absorption)
- Input resource of ancillary data or MODIS product
- Spectral band and detector status (L1B)
- Occurrence of contamination by thin cirrus

Two common retrieval processing flags are the processing path flag and the input data resource flag. The former indicates the retrieval path, the correction due to Rayleigh scattering and gaseous absorption, or the occcurrence of error during retrieval. The latter is to indicate the source of input data sets, such as other MODIS products, ancillary data from other satellites, model assimilated data from GMAO (Goddard Modeling and Assimilation Office), or NCEP (National Centers for Environmental Prediction), or climatology.

2.2 Reading and Interpreting Runtime QA Flags

All Level 2 (L2) MODIS Atmosphere HDF data products contain one or more "bit flag"" Scientific Data Set (SDS) arrays. Bit flag SDS names may contain the string "Quality_Assurance"" or may have a more descriptive name like "Cloud_Mask". However, they all have one common attribute — bit flag (or bit string) arrays contain multiple flags stored in particular (fixed) bit positions of the array.

Bit and Byte Array Indexing Convention: "Zero-based"

The convention for indexing arrays varies from language to language. Array indexing in FORTRAN typically starts at 1; and array indexing in C typically starts at 0. However, almost all tools used for bit extraction (in both FORTRAN and C) use an index start convention of 0 for both bits and bytes. In addition, the HDF interface is based in the C (0-based) language. Therefore a 0-based start convention for indexing (numbering) the bits and bytes is always used. In summary, the first byte is always called byte 0, and the first bit is always called bit 0.

HDF Bit and Byte Array Ordering Convention: "Big Endian"

Background on "endian" nomenclature and its impact on bit string dumps

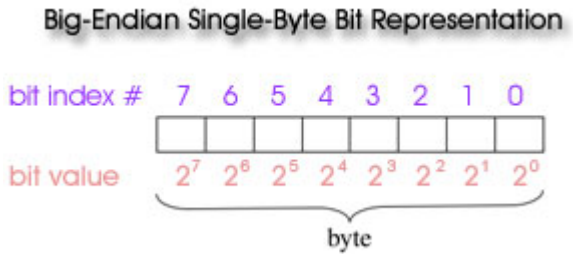
There are two schemes of byte (or bit) ordering used in computers: *big endian* and *little endian*.

- ***Little endian*** means that the low-order byte (or bit) is stored in memory at the lowest (leftmost) address, and the high-order byte (or bit) at the highest (rightmost) address (in other words, the "little end" comes first.). Intel processors (those used in Windows PCs) use the *little endian* convention. This group also includes HP-UX and PC-based Linux.

- ***Big endian*** means that the high-order byte (or bit) is stored in memory at the lowest (leftmost) address, and the low-order byte at the highest (rightmost) address (in other words, the "big end" comes first.). Motorola processors (those used in Macintosh OS) use the *big endian* convention. This group also includes Sun OS and SGI/Irix.

If one uses a tool that dumps (displays) bit registers (e.g., 01001001) of an HDF bit flag SDS array, one needs to keep in mind that standard HDF data products (including all MODIS HDF data) are dumped (displayed) using the ***big endian*** referencing scheme.

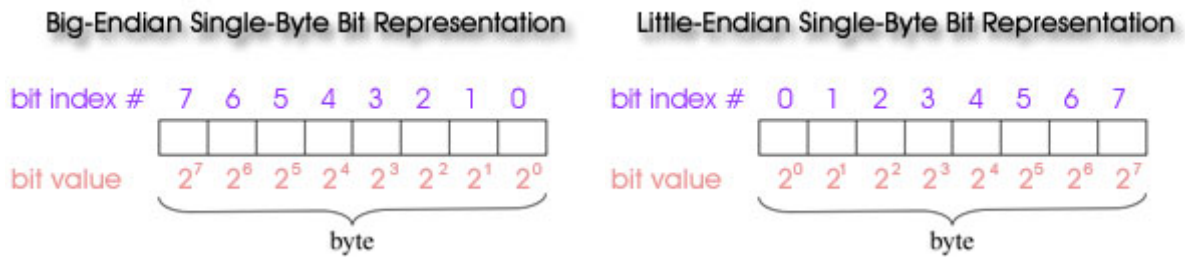
Since HDF is designed to be platform-independent, if the platform being used is *little endian*, the HDF library will (automatically) convert the bit and byte order of bit flag SDS arrays to *big endian*. On *big endian* platforms, the HDF library will perform no byte-order conversion since the array already in the correct form by default. Therefore, when "stripping bits"" from *bit flag* SDSs (Quality Assurance or Cloud Mask arrays, for example) using bit manipulation tools, the bits will **always** be numbered from right (bit index #0) to left (bit index #7). That is, the least significant bit (2^0) is on the right and most significant bit (2^7) is on the left. A visual example of this format is offered below.



Numerical Whole-Byte Dumps

Users should note that if one uses the HDF utility, *ncdump,* or other tools to dump full-byte values (numbers from 0 to 255) from *bit flag* SDS arrays; one can recreate the *bit flags* using **either** the *big* or *little endian* convention. One simply converts the numbers to 8 bit registers of 0 or 1, where the bit tagged as the first bit (bit index #0) is

the lowest order (or least significant) bit (2^0); and the bit tagged as the last bit (bit index #7) is the highest order (or most significant) bit (2^7). In this case, it doesn't matter which end (left or right) one places the least significant (2^0) bit.



To decode individual flags, one queries groups of sequential bits (matching the length of each flag) in the proper bit order from 0 to 7 and interprets the value of those bits (using the same *least significant* to *most significant* convention) to obtain the correct flag value. An example of both of these (*bit flag* decoding) methods is detailed below.

Example: Interpreting the Cloud_Mask SDS (1st byte only)

Consider the first byte of the (commonly used) Cloud_Mask SDS:

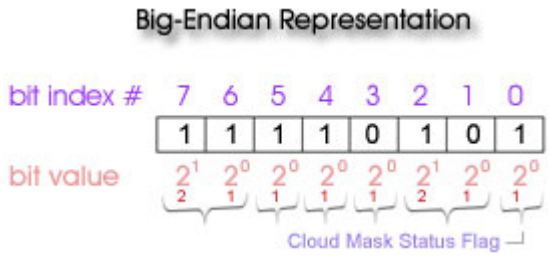
Bits	Flag Name	Bit Values	Bit Value Definitions
0	Cloud Mask Status Flag	0 1	Undetermined Determined
1-2	Cloud Mask Cloudiness Flag	0 1 2 3	Confident Cloudy (or Fill, if Status Flag = 0) Probably Cloudy Probably Clear Confident Clear
3	Day / Night Flag	0 1	Night (or Fill, if Status Flag = 0) Day
4	Sunglint Flag	0 1	Yes (or Fill, if Status Flag = 0) No
5	Snow / Ice Flag	0 1	Yes (or Fill, if Status Flag = 0) No
6-7	Surface Type Flag	0 1 2 3	Ocean or Deep Lakes and Rivers (or Fill) Coast or Shallow Lakes and Rivers Desert Land

Suppose the following flags were set:

- Cloud Mask Status = 1 (Determined)
- Cloud Mask Cloudiness = 2 (Probably Clear)
- Day/Night = 0 (Night)
- Sunglint = 1 (No)
- Snow/Ice = 1 (No)
- Surface Type = 3 (Land)

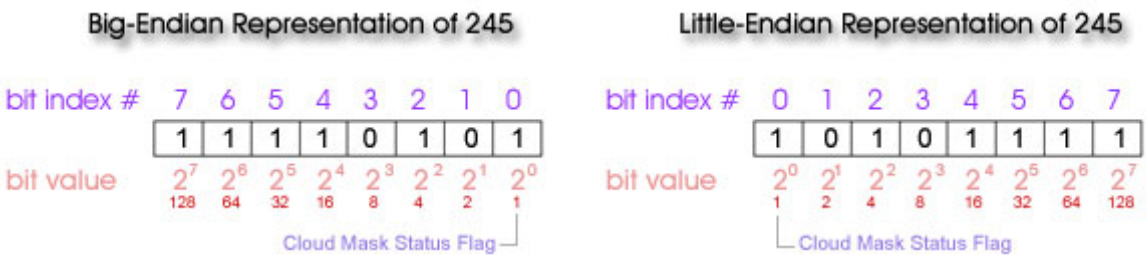
Bit-String Dump

Stripping the bits using a bit manipulation tool would yield the results shown below. Flags are then counted (positioned) from the right (*big endian* convention); and least to most significant bits are ordered from right to left for each flag.



Numerical Whole-Byte Dump

However if one uses the HDF dump utility, *ncdump,* or another tool to dump the full-byte numeric value from the array, one gets a byte value of **245** (for this particular case). One can then recreate the individual bit flags using either the big or little Endian convention, as long as one starts counting (indexing) the bits (and assigning flags) from the least significant to the most significant bit.



Appendix A:

Runtime QA Flags

of

Atmosphere Products

Aerosol Product: MOD04_L2 (Terra) & MYD04_L2 (Aqua)

For the Aerosol product, the Runtime QA flags are stored in three Scientific Data Sets (SDSs): *Cloud_Mask_QA*, *Quality_Assurance_Land*, and *Quality_Assurance_Ocean*. *Cloud_Mask_QA* is a single byte SDS that contains several cloud mask QA flags recomputed on a 10x10 km grid. This recomputation is performed using specific numerical threshholds of percentages of 1 km Cloud Mask pixels that meet certain criteria within the Aerosol 10x10 km retrieval area (see "Bit Value Definitions" column in the table below). So for each 10x10 km pixel, up to one hundred 1 km Cloud Mask pixels are queried. It should be noted that in the previous version of the QA Plan, the 2nd flag in sequence below was incorrectly documented, it is now correctly specified as being "Spares." All other flags provide information on the processing (logic) path taken in the aerosol retrieval algorithm.

Quality_Assurance_Land and *Quality_Assurance_Ocean* are five byte SDSs that contain product quality flags, retrieval processing flags, and input data resource flags designed separately for land and ocean because of differences in the retrieval algorithms. All Aerosol QA Flag arrays have the following characteristics:

- Spatial resolution: 10x10 km
- Processing mode: Daytime only

Scientific Data Set (SDS) Name: ***"Cloud_Mask_QA"***
Description: ***Cloud mask QA flags recomputed at 10x10 km resolution***
Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Mask Summary Flag from internal 04_L2 Cloud Mask	1	0 1	Undetermined (< 100% cloudy) Determined (100% cloudy)
Cloud Mask Quality Flag from internal 04_L2 Cloud Mask	2	0 1 2 3	0% to 30% Cloudy pixels 30% to 60% Cloudy pixels 60% to 90% Cloudy pixels > 90% Cloudy pixels
Spare	1		TBD
Snow / Ice Flag from 35_L2 Cloud Mask	1	0 1	Yes (≥ 90% snow / ice pixels) No (< 90% snow / ice pixels)
Surface Type Flag from 35_L2 Cloud Mask	2	0 1 2 3	Ocean (≥ 90% ocean or deep lakes and rivers) Coast (other criteria not met) Desert (100% desert) Land (100% land and < 100% desert)
Spare	1		TBD

Scientific Data Set (SDS) Name: ***"Quality_Assurance_Land"***
Description: ***Product quality and retrieval processing flags over Land***
Length: ***5 bytes (40 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
0.47 µm Aerosol Optical Thickness Usefulness Flag	1	0 1	Not useful Useful
0.47 µm Aerosol Optical Thickness Confidence Flag	3	0 1 2 3	No Confidence (or Fill) Marginal Good Very Good
0.66 µm Aerosol Optical Thickness Usefulness Flag	1	0 1	Not useful Useful
0.66 µm Aerosol Optical Thickness Confidence Flag	3	0 1 2 3	No Confidence (or Fill) Marginal Good Very Good
processing path flags			
Dark Target Criteria used in retrieval	3	0 1 2 3 4 5	not met (Fill Value) 0.01 < *Ref* (2.1 µm) ≤ 0.05 0.05 < *Ref* (2.1 µm) ≤ 0.10 0.10 < *Ref* (2.1 µm) ≤ 0.15 0.15 < *Ref* (2.1 µm) ≤ 0.25 0.25 < *Ref* (2.1 µm) ≤ 0.40
Error Code (when Fill Values are assigned)	3	0 1 2 3 4 5 6	No error Solar and illumination angles out-of-bounds in look-up table Apparent reflectance out-of-bounds in look-up table Number of cloud and water free pixels not met Thresholds of 2.1 µm not met Thresholds of 3.8 µm not met Thin cirrus detection not met
High Solar Zenith Angle (> 72°)	1	0 1	No Yes
Increased Spatial Resolution (5x5 km)	1	0 1	No Yes

Aerosol Type (over Land only)	2	0 1 2 3	Mixed Dust Sulfate Smoke
Thin Cirrus or Stratospheric Aerosol Index	2	0 1 2 3	0 < ρ (1.38 μm) < 0.01; Correction is done ρ (1.38 μm) < 0; No correction ρ (0.66 μm) < 0.04; No correction ρ (1.38 μm) > 0.01; No correction
input data resource flags			
Total ozone	2	0 1 2 3	TOVS TOMS Climatology GMAO
Total Precipitable Water	2	0 1 2 3	NCEP / GDAS MOD05* NIR (MODIS Near-IR Water Vapor Retrieval) Climatology GMAO
Snow Cover	2	0 1	MOD35* (MODIS Cloud Mask) MOD10* (MODIS Eight-day Snow Cover)
Spares	6		TBD
Deep Blue Aerosol Usefulness Flag $	1	0 1	Not useful Useful
Deep Blue Aerosol Confidence Flag $	2	0 1 2 3	No Confidence (or Fill) Marginal Good Very Good
Deep Blue Aerosol Type $	2	0 1 2 3	Mixed Dust Sulfate Smoke
Deep Blue Aerosol Retrieving Condition $	2	0 1 2 3	Optimal Retrieval Performed White Sand Cloudy τ(550 nm) > 5.0 (Out of Bounds)
Spare	1		TBD

* MOD prefix denotes MODIS/Terra (AM overpass) data -- MYD prefix should be substituted for MODIS/Aqua (PM overpass) data

$ Implemented in PGE04 versions 5.3.0 and later (Initially implemented in the Collection 005 Aqua reprocess)

Scientific Data Set (SDS): ***"Quality_Assurance_Ocean"***
Description: ***Product quality and retrieval processing flags over Ocean***
Length: ***5 bytes (40 bits)***

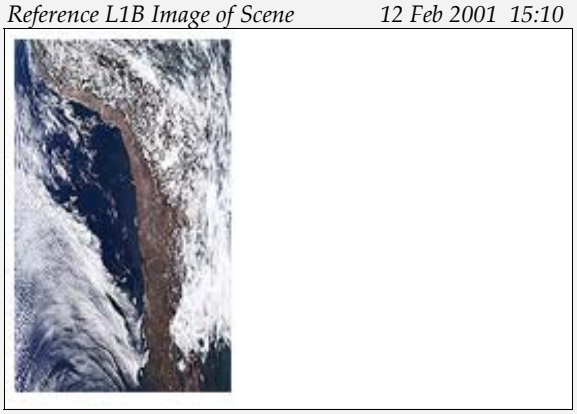
Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Aerosol Parameters (Best Soln.) Usefulness Flag	1	0	Not useful
		1	Useful
Aerosol Parameters (Best Soln.) Confidence Flag	3	0	No Confidence (or Fill)
		1	Marginal
		2	Good
		3	Very Good
Aerosol Parameters (Avg. Soln.) Usefulness Flag	1	0	Not useful
		1	Useful
Aerosol Parameters (Avg. Soln.) Confidence Flag	3	0	No Confidence (or Fill)
		1	Marginal
		2	Good
		3	Very Good
processing path flags			
Part I: Aerosol over Ocean Retrieving Condition when inversion is NOT performed.	4	0	Retrieval is performed
		1	Glitter is present
		2	Cloudy
		3	*R* (0.865 μm) too low for retrieving optical thickness
Note: τ (550 nm) ***fill value*** *will be output on conditions 1 through 10.*		4	Total number of available VIS / SWIR wavelength bands (from 550 to 1240 nm) is insufficient
		5	Total number of available wavelengths < 3
		6	Angles Out-of-Bounds
		7	Land present in 10 x 10 km box
		8	τ (550 nm) < -0.01; algorithm found negative values of optical thickness (there is a problem)
		9	τ (550 nm) > 5.0; out of bounds in lookup table
		10	All Channels do not have valid data

Part II: Aerosol over Ocean Retrieving Condition when inversion IS performed. *Note: τ (550 nm) **retrieved value** will be output.on conditions 0 through 10.* *Confidence Flag Notes:* • *If Retrieving Condition = 0, then Confidence. Flag is set to Very Good.* • *If = 7, then Confidence Flag is set to Good.* • *If = 1, 3, 4, 6, 8 or 10, then Confidence Flag is set to Marginal.* • *If = 2, 5, or 9, then Confidence Flag is set to No Confidence.*	4	0 1 2 3 4 5 6 7 8 9 10 11	Retrieval performed normally Number of useful pixels within 10 x 10 km box is < 10% *R* (0.865 μm) low but large enough for retrieving optical thickness; the size distribution is questionable; η = fill value 1.65 μm channel not used 2.13 μm channel not used 1.65 and 2.13 μm channels not used Aerosol type as well as aerosol content are variable There is variability in aerosol content but the spectral dependence is stable The best value of ε is larger than the threshold value (5%) τ (550 nm) < 0 to avoid bias in level 3 product Glint angle between 30° and 40° Glint; Store only Refl., SD, and Number of Pixels Used
input data resource flags			
Total Ozone	2	0 1 2 3	TOMS TOVS GMAO Climatology
Total Precipitable Water	2	0 1 2 3	NCEP MOD05* NIR (MODIS Near-IR Water Vapor Retrieval) GMAO MOD05* IR (MODIS IR Water Vapor Retrieval)
Snow Cover	2	0 1 2 3	No snow detected MOD35* (MODIS Cloud Mask) MOD10* (MODIS Eight-day Snow Cover) Other
Spares	2		TBD
Spares	8		TBD
Spares	8		TBD

* MOD prefix denotes MODIS/Terra (AM overpass) data -- MYD prefix should be substituted for MODIS/Aqua (PM overpass) data

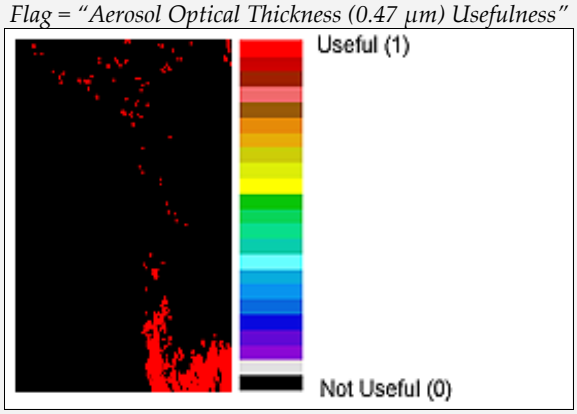
Sample Runtime QA Flag Images
from the Aerosol Product

Reference L1B Image of Scene *12 Feb 2001 15:10*



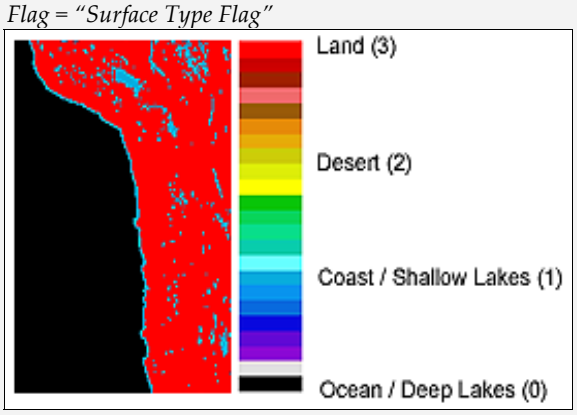
MODIS Terra (AM) *R:G:B = Band 1 : Band 4 : Band 3*

Flag = "Aerosol Optical Thickness (0.47 µm) Usefulness"



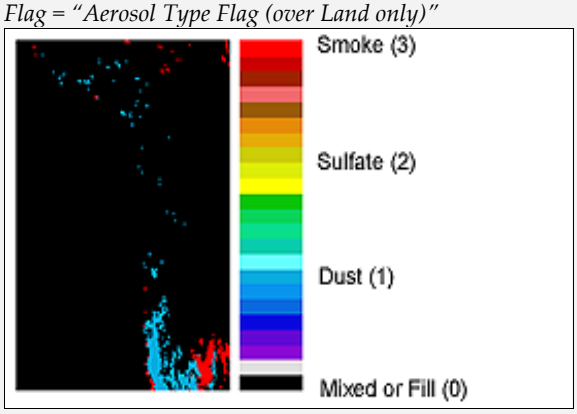
SDS = "Quality_Assurance_Land" *(Aerosol over Land)*

Flag = "Surface Type Flag"



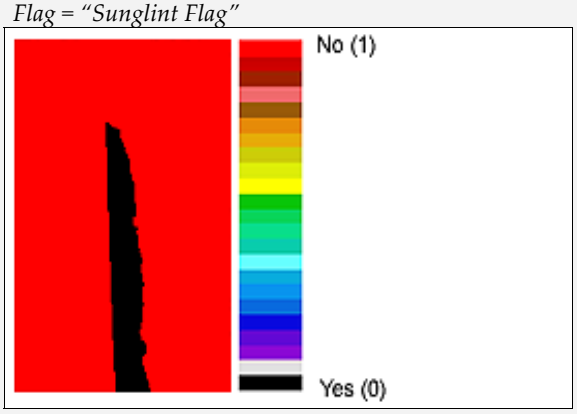
SDS = "Cloud_Mask_QA" *(Cloud Mask)*

Flag = "Aerosol Type Flag (over Land only)"



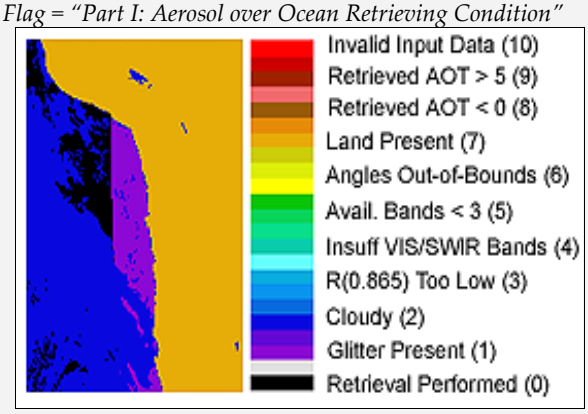
SDS = "Quality_Assurance_Land" *(Aerosol over Land)*

Flag = "Sunglint Flag"



SDS = "Cloud_Mask_QA" *(Cloud Mask)*

Flag = "Part I: Aerosol over Ocean Retrieving Condition"



SDS = "Quality_Assurance_Ocean" *(Aerosol over Ocean)*

Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Water Vapor Product: MOD05_L2 (Terra) & MYD05_L2 (Aqua)

The Water Vapor (or Total Precipitable Water) product combines results from both the NIR (1×1 km) and IR algorithms (5 × 5 km). For near infrared (NIR) total precipitable water, the first byte contains cloud mask QA (1 × 1 km), and the second byte (a separate array from the cloud mask QA) contains NIR product quality and retrieval processing flags. For the five bytes of IR total precipitable water results, only product quality and retrieval processing flags are stored. Since IR total precipitable water results are copied from 07_L2, the cloud mask related QA flags can be retrieved from 07_L2, and therefore it will not be duplicated here in the 05_L2 product. All Water Vapor QA Flag arrays have the following characteristics:

- Spatial resolution: 1 × 1 km (NIR) and 5 × 5 km (IR)
- Processing mode: Daytime only (NIR) and Both Day and Night (IR)

Scientific Data Set (SDS): ***"Cloud_Mask_QA"***
Description: ***Cloud mask QA flags at 1x1 km***
Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Mask Status Flag	1	0	Undetermined
		1	Determined
Cloud Mask Cloudiness Flag	2	0	Confident Cloudy (or Fill, if Status Flag = 0)
		1	Probably Cloudy
		2	Probably Clear
		3	Confident Clear
Day / Night Flag	1	0	Night (or Fill, if Status Flag = 0)
		1	Day
Sunglint Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Snow / Ice Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Surface Type Flag	2	0	Ocean or Deep Lakes and Rivers (or Fill)
		1	Coast or Shallow Lakes and Rivers
		2	Desert
		3	Land

Scientific Data Set (SDS): ***"Quality_Assurance_Near_Infrared"***
Description: ***Product quality and retrieval processing flags for Precipitable Water (Near IR) at 1x1 km***
Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Total Precipitable Water (NIR) Usefulness Flag	1	0 1	Not useful Useful
Total Precipitable Water (NIR) Confidence Flag	3	0 1 2 3	Bad (or Fill) Marginal Confidence Good Confidence Very Good Confidence
Inversion Method Used (NIR)	2	0 1 2	Two channel ratio Three channel ratio No retrieval
Surface Type	2	0 1 2 3	Bright Land Clear Ocean Cloud Sunglint

Scientific Data Set (SDS): ***"Quality_Assurance_Infrared"***
Description: ***Product quality and retrieval processing flags for Precipitable Water (IR) at 5x5 km***
Length: ***5 bytes (40 bits)***

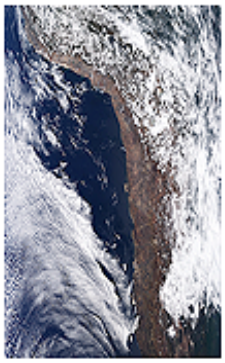
Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Total Precipitable Water (IR) Usefulness Flag[n]	1	0 1	Not useful Useful
Total Precipitable Water (IR) Confidence Flag[n]	3	0 1 2 3	Bad (or Fill) Marginal Confidence Good Confidence *(not currently used)* Very Good Confidence *(not currently used)*
Spares	4		TBD
Number of Cloudy Pixels	Int 8	0-25	Number of 1 km Cloudy pixels n 5x5 retrieval area
Number of Clear Pixels	Int 8	0-25	Number of 1 km Clear pixels in 5x5 retrieval area
Number of Missing Pixels	Int 8	0-25	Number of 1 km Missing pixels in 5x5 retrieval area
IR Water Vapor Retrieval Method Used	2	0 1 2 3	Split Window (11-12 μm) Technique Integration of Moisture Profile Other No Retrieval
Spares	6		TBD

[n] Flag is not reliable in Not Useful / Bad regions (i.e. Not Useful pixels are incorrectly tagged as Useful, etc. about ½ the time.)

Sample Runtime QA Flag Images

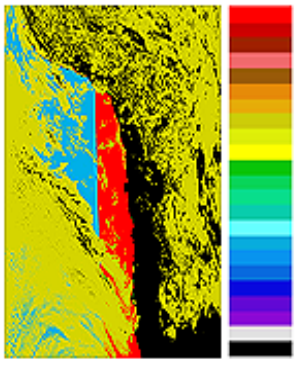
from the Water Vapor Product

Reference L1B Image of Scene *12 Feb 2001 15:10*



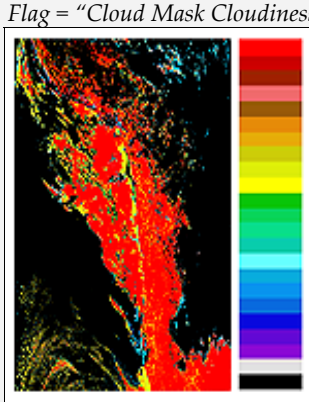
MODIS Terra (AM) *R:G:B = Band 1 : Band 4 : Band 3*

Flag = "Surface Type Flag (NIR Retrieval)"



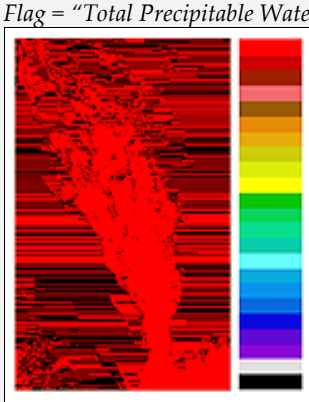
SDS = "Quality_Assurance_Near_Infrared" *(NIR Water Vapor)*

Flag = "Cloud Mask Cloudiness Flag"



SDS = "Cloud_Mask_QA" *(Cloud Mask)*

Flag = "Total Precipitable Water (IR) Usefulness Flag" [1]



SDS = "Quality_Assurance_Infrared" *(IR Water Vapor)*

[1] TPWIR Flags are copied from the 07_L2 Atmospheric Profile product - - and all 07_L2 Atmospheric Profile Usefulness and Confidence Flags are noisy.

Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Cloud Product: MOD06_L2 (Terra) & MYD06_L2 (Aqua)

The MODIS Cloud product consists of both a 1 km set of parameters derived from solar reflectance channels (Cloud Optical Properties and Cirrus Reflectance) and a 5 km set of parameters determined from thermal emitted channels (Cloud Top Properties). It should be noted that only the Cloud Optical Property and Cloud Top Property parameter sets have QA flags associated with them.

Cloud Optical Properties

Cloud Optical Property QA flags are stored in 2 separate QA arrays (SDS's). The first SDS (*Cloud_Mask_1km*, 2 bytes in length) contains cloud mask QA flags, which are copied from the 35_L2 Cloud Mask product. The second SDS (*Quality_Assurance_1km*, 5 bytes in length) contains the product quality flags, retrieval processing flags, and scene characteristic flags. Detail on the content of these two arrays is provided below. All Cloud Optical Property QA Flag arrays have the following characteristics:

- Spatial resolution: 1 x 1 km
- Processing mode: Daytime only

Scientific Data Set (SDS): ***"Cloud_Mask_1km"***
Description: ***Cloud mask QA flags at 1x1 km***
Length: ***2 bytes (16 bits)***

Flag Name	Number of Bits	Bit Value	Bit Value Definitions
Cloud Mask Status Flag	1	0	Undetermined [n,f]
		1	Determined
Cloud Mask Cloudiness Flag	2	0	Confident Cloudy (or Fill, if Status Flag = 0)
		1	Probably Cloudy
		2	Probably Clear
		3	Confident Clear
Day / Night Flag	1	0	Night [n,f] (or Fill, if Status Flag = 0)
		1	Day
Sunglint Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Snow / Ice Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Surface Type Flag	2	0	Ocean or Deep Lakes and Rivers (or Fill)
		1	Coast or Shallow Lakes and Rivers
		2	Desert
		3	Land
Heavy Aerosol Flag	1	0	Yes [n,f] (or Fill, if Status Flag = 0)
		1	No

Thin Cirrus Flag *(Based on low threshold using 1.38 μm band.)*	1	0 1	Yes (or Fill, if Status Flag = 0) No
Shadow Flag	1	0 1	Yes [n,f] (or Fill, if Status Flag = 0) No
Spares	5		TBD

[n] Cloud Optical Property retrieval not attempted

[f] fill values used for Cloud Optical Property retrieval

Scientific Data Set (SDS): ***"Quality_Assurance_1km"***

Description: ***Cloud Optical Property product quality and retrieval processing QA flags at 1x1 km***

Length: ***5 bytes (40 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Optical Thickness (τ) Usefulness Flag	1	0 1	Not useful Useful
Cloud Optical Thickness (τ) Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
Cloud Optical Thickness (τ) Out-of-Bounds Flag	2	0 1 2	Within bounds ($0 < \tau \leq 100$) or Fill $100 < \tau \leq 150$ $\tau > 150$
Cloud Effective Radius Usefulness Flag	1	0 1	Not useful Useful
Cloud Effective Radius Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
Cloud Water Path Usefulness Flag	1	0 1	Not useful Useful
Cloud Water Path Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
1.6 / 2.1 μm Cloud Retrieval Phase Flag *Note: Retrieval performed only over ocean, snow, & ice. Cloud phase determined by Cloud Mask, IR, & SWIR-based decision tree.*	3	0 1 2 3 4	Cloud Mask Undetermined or Non-Snow Land [n,f] Not Processed (typ. clear) over Ocean, Snow, Ice [f] Liquid Water Cloud Ice Cloud Undetermined Phase Cloud
1.6 / 2.1 μm Cloud Retrieval Outcome	1	0 1	1.6 / 2.1 μm retrieval not attempted or unsuccesful [f] 1.6 / 2.1 μm retrieval successful

Spare	1		TBD
Primary Cloud Retrieval Phase Flag *Note: Cloud phase determined by Cloud Mask, IR, & SWIR-based decision tree.*	3	0 1 2 3 4	Cloud Mask Undetermined [n,f] Not Processed (typically clear) [f] Liquid Water Cloud Ice Cloud Undetermined Phase Cloud
Primary Cloud Retrieval Outcome	1	0 1	Retrieval not attempted or unsuccesful [f] Retrieval successful
Rayleigh Correction	1	0 1	No Yes
Atmospheric Correction	1	0 1	No Yes
Band Used for Primary Optical Thickness Retrieval	2	0 1 2 3	Retrieval not attempted [f] 0.645 µm (land) 0.858 µm (water) 1.24 µm (snow / ice)
1.6 / 2.1 µm Cloud Optical Thickness (τ) Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Optical Thickness (τ) Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
1.6 / 2.1 µm Cloud Effective Radius Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Effective Radius Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
Clear Sky Restoral	2	0 1 2 3	Not Restored Restored via Edge Detection Restored via Spatial Variance Restored via 250 m Tests
1.6 / 2.1 µm Cloud Water Path Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Water Path Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence

Primary Cloud Retrieval Multilayer Cloud & Phase Flag	3	0	Cloud mask undetermined [n,f]
		1	Not Processed (typically clear) [f]
		2	Single Layer Liquid Water Cloud
		3	Multi Layer Liquid Water Cloud
		4	Single Layer Ice Cloud
		5	Multi Layer Ice Cloud
		6	Single Layer Undetermined Phase Cloud
		7	Multi Layer Undetermined Phase Cloud
Primary Cloud Retrieval Outcome (flag duplicated from 3rd byte)	1	0	Retrieval not attempted or unsuccesful [f]
		1	Retrieval successful
Spare	1		TBD

[n] Cloud Optical Property retrieval not attempted

[f] fill values used for Cloud Optical Property retrieval

Cloud Top Properties

Cloud Top Property QA flags are stored in 2 separate QA arrays (SDS's). The first SDS (*Cloud_Mask_5km*, 1 byte in length) contains cloud mask QA flags, which are subsampled (every 5th line, every 5th pixel) from the Cloud Mask (35_L2) product. The second SDS (*Quality_Assurance_5km*, 10 bytes in length) contains the product quality flags, retrieval processing flags, and and input data resource flags. Detail on the content of these two arrays is provided below. All Cloud Top Property QA Flag arrays have the following characteristics:

- Spatial resolution: 5 × 5 km
- Processing mode: Both Day and Night

Scientific Data Set (SDS): ***"Cloud_Mask_5km"***
Description: ***Cloud mask 1 km QA flags subsampled at 5 km (every 5th line, every 5th pixel)***
Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Mask Status Flag	1	0	Undetermined
		1	Determined
Cloud Mask Cloudiness Flag	2	0	Confident Cloudy (or Fill, if Status Flag = 0)
		1	Probably Cloudy
		2	Probably Clear
		3	Confident Clear
Day / Night Flag	1	0	Night (or Fill, if Status Flag = 0)
		1	Day
Sunglint Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Snow / Ice Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Surface Type Flag	2	0	Ocean or Deep Lakes and Rivers (or Fill)
		1	Coast or Shallow Lakes and Rivers
		2	Desert
		3	Land

Scientific Data Set (SDS): ***"Quality_Assurance_5km"***
Description: ***Cloud Top Property product quality and retrieval processing QA flags at 5x5 km***
Length: ***10 bytes (80 bits)***

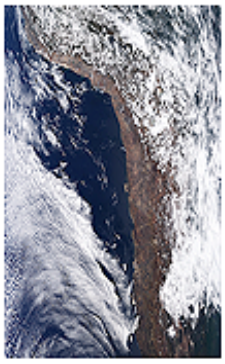
Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Top Pressure Usefulness Flag	1	0 1	Not useful Useful
Cloud Top Pressure Confidence Flag	3	0 1 2 3	Fill Marginal Confidence *(not currently used)* Good Confidence *(not currently used)* Very Good Confidence
Cloud Top Temperature Usefulness Flag	1	0 1	Not useful Useful
Cloud Top Temperature Confidence Flag	3	0 1 2 3	Fill Marginal Confidence *(not currently used)* Good Confidence *(not currently used)* Very Good Confidence
Cloud Fraction Usefulness Flag	1	0 1	Not useful Useful
Cloud Fraction Confidence Flag	3	0 1 2 3	Fill Marginal Confidence *(not currently used)* Good Confidence *(not currently used)* Very Good Confidence
Cloud Effective Emissivity Usefulness Flag	1	0 1	Not useful Useful
Cloud Effective Emissivity Confidence Flag	3	0 1 2 3	Fill Marginal Confidence *(not currently used)* Good Confidence *(not currently used)* Very Good Confidence
Cloud Phase Infrared Usefulness Flag	1	0 1	Not useful Useful
Cloud Phase Infrared Confidence Flag	3	0 1 2 3	Fill Marginal Confidence *(mixed or undetermined phase)* Good Confidence *(not currently used)* Very Good Confidence *(ice or liquid water phase)*
processing path flags			
"Cirrus" Flag (CTP ≤ 700 hPa & CEE ≤ 0.95) *Note: This Flag was NOT working prior to Collection 005.*	2	0 1 2	0 - Missing 1 - No cirrus found 2 - Cirrus found

"High Cloud" Flag (CTP < 400 hPa)	2	0 1 2	0 - Missing 1 - No high cloud found 2 - High cloud found
Number of Cloudy Pixels	Int 8	0-25	Number of 1 km cloudy pixels in 5x5 km retrieval area
Number of Clear Pixels	Int 8	0-25	Number of 1 km clear pixels in 5x5 km retrieval area
Number of Missing Pixels	Int 8	0-25	Number of 1 km missing pixels in 5x5 km retrieval area
input data resource flags			
Spares	6		TBD
Clear Radiance Origin	2	0 1 2	MOD35* (MODIS Cloud Mask) Forward calculation from model (NCEP GDAS) Other
Moisture Profile	2	0 1 2 3	NCEP GDAS GMAO AIRS / AMSU Other
Temperature Profile	2	0 1 2 3	NCEP GDAS GMAO AIRS / AMSU Other
Surface Temperature Over Land	2	0 1 2 3	NCEP GDAS GMAO MOD11* (MODIS Land Surface Temperature) Other
Surface Temperature Over Ocean	2	0 1 2 3	Reynolds blended GMAO MOD28* (MODIS Sea Surface Temperature) Other
Surface Pressure	2	0 1 2	NCEP GDAS GMAO Other
Topography	2	0 1	EOS DEM Other
Surface Emissivity	2	0 1	CERES MOD11* (MODIS Land Surface Temperature)
Surface Type	2	0 1 2 3	Loveland 1 km NA Olson Ecosystem MOD12* (MODIS Land Cover) Other
Spares	8		TBD

* MOD prefix denotes MODIS/Terra (AM overpass) data -- MYD prefix should be substituted for MODIS/Aqua (PM overpass) data.

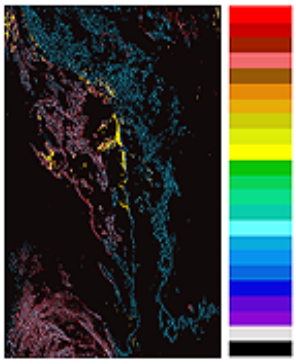
Sample Runtime QA Flag Images
from the Cloud Product

Reference L1B Image of Scene *12 Feb 2001 15:10*



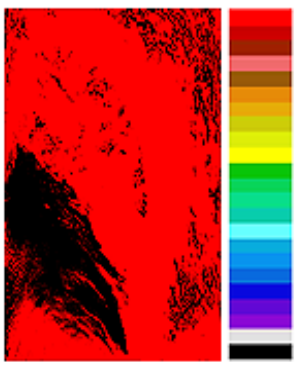
MODIS Terra (AM) *R:G:B = Band 1 : Band 4 : Band 3*

Flag = "Clear Sky Restoral"



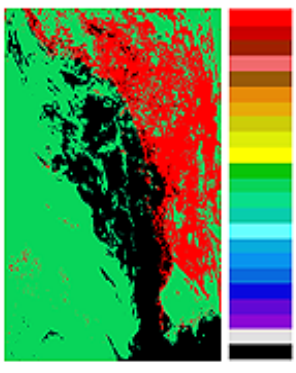
SDS = "Quality_Assurance_1km" *(Cloud Optical Properties)*

Flag = "Thin Cirrus Flag" [1] *(Low Threshold using 1.38 μm)*



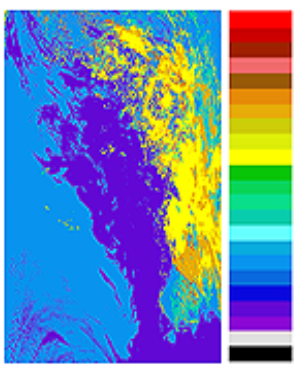
SDS = "Cloud_Mask_1km" *(Cloud Mask)*

Flag = "Cirrus Flag" *(CTP ≤ 700 hPa & CEE ≤ 0.95)*



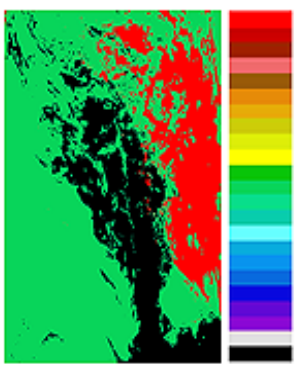
SDS = "Quality_Assurance_5km" *(Cloud Top Properties)*

Flag = "Multilayer Cloud and Phase Flag"



SDS = "Quality_Assurance_1km" *(Cloud Optical Properties)*

Flag = "High Cloud Flag" *(CTP < 400 hPa)*



SDS = "Quality_Assurance_5km" *(Cloud Top Properties)*

[1] Note: "Thin Cirrus Flag" from Cloud Mask is suspect *(due to 1.38 μm test limitations)* for portions of this granule.

Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Atmospheric Profile Product: MOD07_L2 (Terra) & MYD07_L2 (Aqua)

Atmospheric Profile QA flags are stored in 3 separate QA arrays (SDS's). The first SDS (*Cloud_Mask*, 1 byte in length) contains cloud mask QA flags, which are subsampled (every 5th line, every 5th pixel) from the Cloud Mask (35_L2) product. The second SDS (*Quality_Assurance*, 10 bytes in length) contains the product quality flags, retrieval processing flags, and and input data resource flags for all products except Water Vapor. The third SDS (*Quality_Assurance_Infrared*, 5 bytes in length) contains the product quality flags, retrieval processing flags, and and input data resource flags for Water Vapor (using the IR method). Detail on the content of these three arrays is provided below. All Atmospheric Profile QA Flag arrays have the following characteristics:

- Spatial resolution: 5 × 5 km
- Processing mode: Both Day and Night

Scientific Data Set (SDS): ***"Cloud_Mask"***

Description: ***Cloud Mask QA flags subsampled at 5 km (every 5th line, every 5th pixel)***

Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Mask Status Flag	1	0	Undetermined
		1	Determined
Cloud Mask Cloudiness Flag	2	0	Confident Cloudy (or Fill, if Status Flag = 0)
		1	Probably Cloudy
		2	Probably Clear
		3	Confident Clear
Day / Night flag	1	0	Night (or Fill, if Status Flag = 0)
		1	Day
Sunglint Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Snow / Ice Flag	1	0	Yes (or Fill, if Status Flag = 0)
		1	No
Surface Type Flag	2	0	Ocean or Deep Lakes and Rivers (or Fill)
		1	Coast or Shallow Lakes and Rivers
		2	Desert
		3	Land

Scientific Data Set (SDS): ***"Quality_Assurance"***
Description: ***Atmospheric Profile product quality and retrieval processing QA flags at 5x5 km***
Length: ***10 bytes (80 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Retrieved Temperature Profile $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Retrieved Temperature Profile $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
Retrieved Moisture Profile $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Retrieved Moisture Profile $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
Total Ozone Burden $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Total Ozone Burden $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
Stability Indices (Lifted Index) $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Stability Indices (Lifted Index) $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
Stability Indices (K Index) $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Stability Indices (K Index) $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
Stability Indices (Total Totals) $_n$ Usefulness Flag	1	0	Not useful
		1	Useful
Stability Indices (Total Totals) $_n$ Confidence Flag	3	0	Bad (or Fill)
		1	Marginal Confidence
		2	Good Confidence *(not currently used)*
		3	Very Good Confidence *(not currently used)*
processing path flags			
Number of Cloudy Pixels	Int 8	0-25	Number of 1km cloudy pixels in 5x5 km retrieval area

Number of Clear Pixels	Int 8	0-25	Number of 1km clear pixels in 5x5 km retrieval area
Number of Missing Pixels	Int 8	0-25	Number of 1km missing pixels in 5x5 km retrieval area
Method of Profiles Retrieval	2	0 1 2 3	Statistical Physical Other No retrieval
Method of Ozone Retrieval	2	0 1 2 3	RTE Perturbation Upper and Lower stratospheric ozone method Other No retrieval
Spares	4		TBD
input data resource flags			
Guess Moisture profile	2	0 1 2 3	NCEP GDAS GMAO AIRS / AMSU Other
Guess Temperature Profile	2	0 1 2 3	NCEP GDAS GMAO AIRS / AMSU Other
Surface Temperature Over Land	2	0 1 2	NCEP GDAS GMAO MOD11* (MODIS Land Surface Temperature)
Surface Temperature Over Ocean	2	0 1 2 3	Reynolds blended GMAO MOD28* (MODIS Sea Surface Temperature) Other
Surface Pressure	2	0 1 2	NCEP GDAS GMAO Other
Ozone First Guess Profile	2	0 1 2 3	TOMS TOVS GMAO Other
Spares	4		TBD
Spares	8		TBD

* MOD prefix denotes MODIS/Terra (AM overpass) data -- MYD prefix should be substituted for MODIS/Aqua (PM overpass) data.
[n] Flag is not reliable in Not Useful / Bad regions (i.e. Not Useful pixels are incorrectly tagged as Useful, etc. about ½ the time.)

Scientific Data Set (SDS): ***"Quality_Assurance_Infrared"***

Description: ***Product quality and retrieval processing flags for Precipitable Water (IR) at 5x5 km***

Length: ***5 bytes (40 bits)***

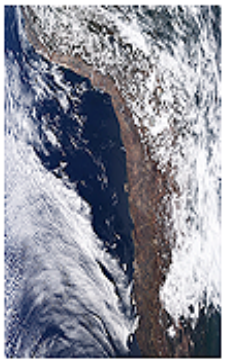
Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Total Precipitable Water (IR) Usefulness Flag[n]	1	0 1	Not useful Useful
Total Precipitable Water (IR) Confidence Flag[n]	3	0 1 2 3	Bad (or Fill) Marginal Confidence Good Confidence *(not currently used)* Very Good Confidence *(not currently used)*
Spares	4		TBD
Number of Cloudy Pixels	Int 8	0-25	Number of 1 km Cloudy pixels n 5x5 retrieval area
Number of Clear Pixels	Int 8	0-25	Number of 1 km Clear pixels in 5x5 retrieval area
Number of Missing Pixels	Int 8	0-25	Number of 1 km Missing pixels in 5x5 retrieval area
IR Water Vapor Retrieval Method Used	2	0 1 2 3	Split Window (11-12 μm) Technique Integration of Moisture Profile Other No Retrieval
Spares	6		TBD

[n] Flag is not reliable in Not Useful / Bad regions (i.e. Not Useful pixels are incorrectly tagged as Useful, etc. about ½ the time.)

Sample Runtime QA Flag Images

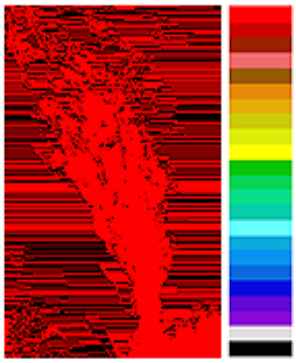
from the Atmospheric Profile Product

Reference L1B Image of Scene *12 Feb 2001 15:10*



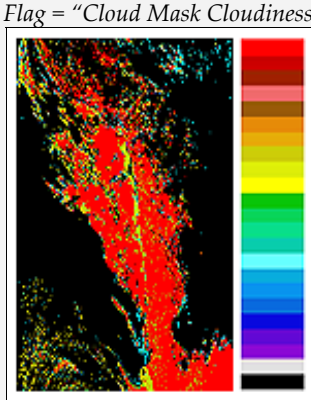
MODIS Terra (AM) *R:G:B = Band 1 : Band 4 : Band 3*

Flag = "Retrieved Temperature Profile Usefulness Flag" [1]



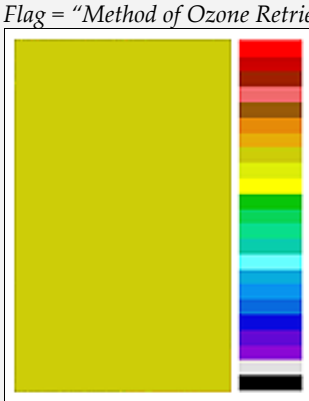
SDS = "Quality_Assurance" *(Atmospheric Profile)*

Flag = "Cloud Mask Cloudiness Flag"



SDS = "Cloud_Mask" *(Cloud Mask)*

Flag = "Method of Ozone Retrieval"



SDS = "Quality_Assurance" *(Atmospheric Profile)*

[1] All 07_L2 Atmospheric Profile Usefulness (and Confidence) Flags are noisy.

Collection 006 Suggestion: Remove noise from all Usefulness and Confidence Flags in the 07_L2 Atmospheric Profile product.

Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Note: The local version of the Cloud Mask QA flags in the 07_L2 Atmospheric Profile product are stored in an SDS named "Cloud_Mask." Users should note that this array is different from the primary "Cloud_Mask" array stored in 35_L2 Cloud Mask product, which has the same name.

Cloud Mask Product: MOD35_L2 (Terra) & MYD35_L2 (Aqua)

For the Cloud Mask product, the QA flags are stored in a single ten byte SDS (called *Quality_Assurance*) containing the product quality flags, retrieval processing flags and input data resource flags. The Cloud Mask QA Flag array has the following characteristics:

- Spatial resolution: 1 × 1 km and 250 × 250 m
- Processing mode: Both Day and Night

Scientific Data Set (SDS): ***"Quality_Assurance"***
Description: ***Cloud Mask QA flags at 1 km and 250 m***
Length: ***10 bytes (80 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Mask (1 km) Usefulness Flag	1	0 1	Not useful Useful
Cloud Mask (1 km) Confidence Flag	3	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
Spares	4		TBD
individual test application flags			
Non Cloud Obstruction (NCO) Test *(Spectral tests for fire, smoke, & dust)*	1	0 1	Not Applied Applied
Thin Cirrus (Solar) Test	1	0 1	Not Applied Applied
Shadow Detection Test	1	0 1	Not Applied Applied
Thin Cirrus (IR) Test	1	0 1	Not Applied Applied
Cloud Adjacency Test	1	0 1	Not Applied Applied
IR Threshold Test	1	0 1	Not Applied Applied
High Cloud (CO_2) Test	1	0 1	Not Applied Applied
High Cloud (6.7 µm) Test	1	0 1	Not Applied Applied
High Cloud (1.38 µm) Test	1	0 1	Not Applied Applied
High Cloud (3.7-12 µm) Test	1	0 1	Not Applied Applied

IR Temperature Difference Test	1	0 1	Not Applied Applied
3.7-11 µm Test	1	0 1	Not Applied Applied
0.68 µm Reflectance Test	1	0 1	Not Applied Applied
Visible Ratio Test	1	0 1	Not Applied Applied
Near IR Reflectance Ratio Test	1	0 1	Not Applied Applied
3.7-3.9 µm Test	1	0 1	Not Applied Applied
Temporal Consistency Test	1	0 1	Not Applied Applied
Spatial Variability Test	1	0 1	Not Applied Applied
Spares	6		TBD
250 m Visible Tests (Repeated 16 times)	1 (16)	0 1	Not Applied Applied
input data information flags			
Number of bands used to generate cloud mask	2	0 1 2 3	None 1-7 8-14 15-21
Number of spectral tests used to generate cloud mask	2	0 1 2 3	None 1-3 4-6 7-9
Spares	4		TBD
input data resource flags			
Clear Radiance Origin	2	0 1 2	MOD35* (MODIS Cloud Mask) Forward calculation from NCEP GDAS model Other
Surface Temperature Over Land	2	0 1 2 3	NCEP GDAS GMAO MOD11* (MODIS Land Surface Temperature) Other
Surface Temperature Over Ocean	2	0 1 2 3	Reynolds blended GMAO MOD28* (MODIS Sea Surface Temperature) Other
Surface Winds	2	0 1 2	NCEP GDAS GMAO Other

Ecosystem Map	2	0 1 2 3	Loveland NA 1 km Olson Ecosystem MOD12* (MODIS Land Cover) Other
Snow Mask	2	0 1 2	MOD33* (MODIS Snow Cover) SSMI product Other
Ice Cover	2	0 1 2	MOD42* (MODIS Sea Ice) SSMI product Other
Land/Sea Mask	2	0 1 2	USGS 1 km 6 level USGS 1 km binary Other
Digital Elevation Model	1	0 1	EOS DEM Not used
Precipitable Water	2	0 1 2	NCEP GDAS GMAO MOD07* (MODIS Atmospheric Profile)
Spares	5		TBD

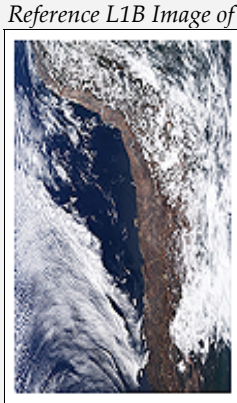
* MOD prefix denotes MODIS/Terra (AM overpass) data -- MYD prefix should be substituted for MODIS/Aqua (PM overpass) data.

Note: All Cloud Mask Tests are described in the Cloud Mask Algorithm Theoretical Basis Document (ATBD).

Sample Runtime QA Flag Images

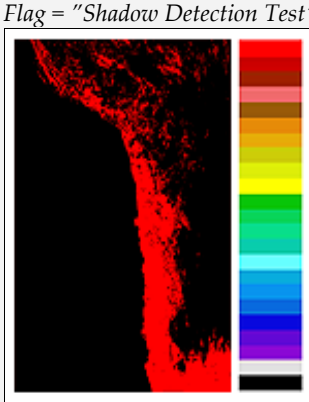
from the Cloud Mask Product

Reference L1B Image of Scene *12 Feb 2001 15:10*



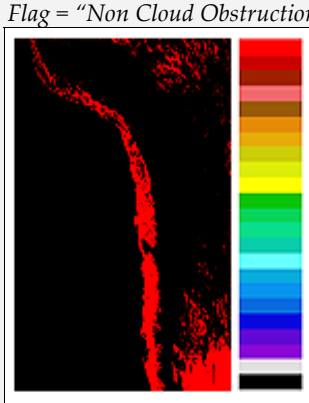
MODIS Terra (AM) *R:G:B = Band 1 : Band 4 : Band 3*

Flag = "Shadow Detection Test"



SDS = "Quality_Assurance" *(Cloud Mask)*

Flag = "Non Cloud Obstruction (NCO) Test"

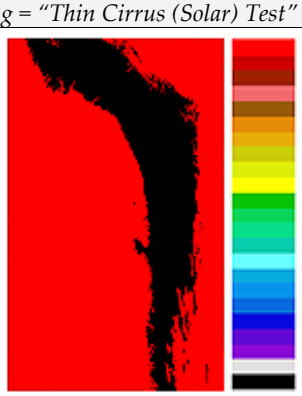


SDS = "Quality_Assurance" *(Cloud Mask)*

Flag = "IR Threshold Test"

SDS = "Quality_Assurance" *(Cloud Mask)*

Flag = "Thin Cirrus (Solar) Test"



SDS = "Quality_Assurance" *(Cloud Mask)*

Flag = "Ecosystem Map"

SDS = "Quality_Assurance" *(Cloud Mask)*

Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Joint Atmosphere Product: MODATML2 (Terra) & MYDATML2 (Aqua)

The *post-launch* Level 2 (L2) Joint Atmosphere product contains a spectrum of key parameters gleaned from the complete set of standard *at-launch* L2 products: Aerosol, Water Vapor, Cloud, Profile, and Cloud Mask. The L2 Joint Atmosphere product was designed to provide a convenient way to obtain the "greatest hits"" of MODIS Atmosphere within a single HDF file — small enough to minimize data transfer and storage requirements, yet robust enough to be useful to a significant number of MODIS data users. Scientific data sets (SDS''s) contained within the L2 Joint Atmosphere product are stored at 5 km and 10 km (at nadir) spatial resolutions.

It should be noted that standard L2 parameters, which are retrieved at 1 km resolution, are subsampled at 5 km (every 5th line, every 5th pixel) for inclusion in the L2 Joint Atmosphere Product. This means that the *Cloud_Quality_Assurance* SDS (detailed below) matches exactly the *Quality_Assurance_1km* SDS contained within the Cloud (06_L2) product, except that it is sub-sampled at 5 km resolution. The *Aerosol_Quality_Assurance* array (also detailed below) is stored at its native resolution of 10 km, however it only contains a small subset of the flags found within the source *Quality_Assurance_Land* and *Quality_Assurance_Ocean* SDS's in the Aerosol (04_L2) product. All Joint Atmosphere QA Flag arrays have the following characteristics:

- Spatial resolution: 5x5 km (Cloud Optical Properties) & 10x10 km (Aerosol)
- Processing mode: Daytime only

Scientific Data Set (SDS): ***"Cloud_Quality_Assurance"***
Description: ***Cloud Optical Property QA flags subsampled at 5 km resolution***
Length: ***5 bytes (40 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Cloud Optical Thickness (τ) Usefulness Flag	1	0	Not useful
		1	Useful
Cloud Optical Thickness (τ) Confidence Flag	2	0	No Confidence or Fill
		1	Marginal Confidence
		2	Good Confidence
		3	Very Good Confidence
Cloud Optical Thickness (τ) Out-of-Bounds Flag	2	0	Within bounds ($0 < \tau \leq 100$) or Fill
		1	$100 < \tau \leq 150$
		2	$\tau > 150$
Cloud Effective Radius Usefulness Flag	1	0	Not useful
		1	Useful
Cloud Effective Radius Confidence Flag	2	0	No Confidence or Fill
		1	Marginal Confidence
		2	Good Confidence
		3	Very Good Confidence

Cloud Water Path Usefulness Flag	1	0 1	Not useful Useful
Cloud Water Path Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
1.6 / 2.1 µm Cloud Retrieval Phase Flag *Note: Retrieval performed only over ocean, snow, & ice. Cloud phase determined by Cloud Mask, IR, & SWIR-based decision tree.*	3	0 1 2 3 4	Cloud Mask Undetermined or Non-Snow Land [n,f] Not Processed (typ. clear) over Ocean, Snow, Ice [f] Liquid Water Cloud Ice Cloud Undetermined Phase Cloud
1.6 / 2.1 µm Cloud Retrieval Outcome	1	0 1	1.6 / 2.1 µm retrieval not attempted or unsuccesful [f] 1.6 / 2.1 µm retrieval successful
Spare	1		TBD
Primary Cloud Retrieval Phase Flag *Note: Cloud phase determined by Cloud Mask, IR, & SWIR-based decision tree.*	3	0 1 2 3 4	Cloud Mask Undetermined (missing) [n,f] Not Processed (typically clear) [f] Liquid Water Cloud Ice Cloud Undetermined Phase Cloud
Primary Cloud Retrieval Outcome	1	0 1	Retrieval not attempted or unsuccesful [f] Retrieval successful
Rayleigh Correction	1	0 1	No Yes
Atmospheric Correction	1	0 1	No Yes
Band Used for Primary Optical Thickness Retrieval	2	0 1 2 3	Retrieval not attempted [f] 0.645 µm (land) 0.858 µm (water) 1.24 µm (snow / ice)
1.6 / 2.1 µm Cloud Optical Thickness (τ) Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Optical Thickness (τ) Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
1.6 / 2.1 µm Cloud Effective Radius Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Effective Radius Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence

Clear Sky Restoral	2	0 1 2 3	Not Restored Restored via Edge Detection Restored via Spatial Variance Restored via 250 m Tests
1.6 / 2.1 µm Cloud Water Path Usefulness Flag	1	0 1	Not useful Useful
1.6 / 2.1 µm Cloud Water Path Confidence Flag	2	0 1 2 3	No Confidence or Fill Marginal Confidence Good Confidence Very Good Confidence
Primary Cloud Retrieval Multilayer Cloud & Phase Flag	3	0 1 2 3 4 5 6 7	Cloud mask undetermined (missing) [n,f] Not Processed (typically clear) [f] Single Layer Liquid Water Cloud Multi Layer Liquid Water Cloud Single Layer Ice Cloud Multi Layer Ice Cloud Single Layer Undetermined Phase Cloud Multi Layer Undetermined Phase Cloud
Primary Cloud Retrieval Outcome (flag duplicated from 3rd byte)	1	0 1	Retrieval not attempted or unsuccesful [f] Retrieval successful
Spare	1		TBD

[n] Cloud Optical Property retrieval not attempted

[f] fill values used for Cloud Optical Property retrieval

Scientific Data Set (SDS): ***"Aerosol_Quality_Assurance"***
Description: ***Aerosol QA flags (a small subset of flags only) at 10x10 km resolution***
Length: ***1 byte (8 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Aerosol Optical Depth Land 0.47 µm Confidence Flag	2	0	No Confidence or Fill
		1	Marginal Confidence
		2	Good Confidence
		3	Very Good Confidence
Aerosol Optical Depth Land 0.66 µm Confidence Flag	2	0	No Confidence or Fill
		1	Marginal Confidence
		2	Good Confidence
		3	Very Good Confidence
Aerosol Optical Depth Ocean Avg. Solution Confidence Flag	2	0	No Confidence or Fill
		1	Marginal Confidence
		2	Good Confidence
		3	Very Good Confidence
Spares	2		TBD

Appendix B:

Inventory Metadata

of

Atmosphere Products

Introduction

This appendix describes the Inventory Metadata for all MODIS Atmosphere products. Inventory Metadata are searchable strings, stored within each HDF file, that can be used to assist users to select granules that meet predetermined criteria. Inventory Metadata are stored in the HDF global attribute "CoreMetadata.0".

There are two main types of Inventory Metadata:

- ***ECS (or Core) Inventory Metadata*** that can be found, in the same format, in all MODIS Atmosphere products. This includes strings that specify *Date/Time Range* and *Bounding Rectangle* (geolocation). Note that ECS stands for EOSDIS Core System.

- ***QA Inventory Metadata***, which is product-specific (i.e.: varies from product to product), and typically provides more scientifically revealing information about a granule.

The primary data archive and ordering system that utilizes the full set of both ECS and QA Inventory Metadata to search and sort MODIS HDF granules is the ***EOS Data Gateway*** (**EDG**, http://redhook.gsfc.nasa.gov/ims-bin/pub/nph-ims.cgi).

Other data archive and ordering systems utilize only a small subset of the ECS (Core) Inventory Metadata. This subset of Core Inventory Metadata utilized typically includes only the *Date/Time Range* and *Bounding Rectangle* (geolocation) strings. These less powerful, but perhaps more user-friendly, data archive and ordering systems include the ***MODIS Multiple Data Ordering Page*** (**MDOP**, http://disc.gsfc.nasa.gov/daac-bin/MODIS/Data_order.pl?PRINT=1) and the ***Atmosphere Archive and Distribution System - Web*** *interface* (**AADSWeb**, http://aadsweb.nascom.nasa.gov).

ECS Inventory Metadata

ECS (or Core) Inventory Metadata is high-level information that can be used to help sort MODIS HDF data files based on basic user requirements. Shown in the table below is the Core Inventory Metadata implemented in all (both Level 2 and Level 3) MODIS Atmosphere products. It includes information on granule location, collection day and time, orbit information, percent missing data, science quality and automatic (operational) quality flags specifically defined to be associated with the measured parameters of a product.

The automatic quality flag is set by the MODIS processing facility (either the Goddard DAAC (Distributed Active Archive Center) or MODAPS) at the time the granule is produced. The science quality flag is assigned initially by the science team, and then updated through an update utility, if desired. Both of these flags are associated with a particular retrieval algorithm and apply to all derived SDSs.

All MODIS Atmosphere Products

ECS (or Core) Inventory Metadata

ECS Core Attribute Name	Sample Value (shown for a L2 Joint Product)
LOCALGRANULEID	"MODATML2.A2001043.1510.005.2005105195411.hdf"
PRODUCTIONDATETIME	"2005-04-15T19:54:11.000Z"
DAYNIGHTFLAG	"Day"
LOCALVERSIONID	"005"
REPROCESSINGACTUAL	"processed once"
REPROCESSINGPLANNED	"further update is anticipated"
SHORTNAME	"MODATML2"
VERSIONID	"5"
PGEVERSION	"5.1.0"
INPUTPOINTER †	"MOD03.A2001043.1510.005.2005105143551.hdf, MOD04_L2.A2001043.1510.005.2005105193145.hdf, MOD05_L2.A2001043.1510.005.2005105193042.hdf, MOD06_L2.A2001043.1510.005.2005105195333.hdf, MOD07_L2.A2001043.1510.005.2005105171354.hdf, MOD35_L2.A2001043.1510.005.2005105171245.hdf"
Date / Time Range	
RANGEBEGINNINGTIME	15:10:00.000000
RANGEENDINGTIME	15:15:00.000000
RANGEBEGINNINGDATE	2001-02-12
RANGEENDINGDATE	2001-02-12
Bounding Rectangle	
EASTBOUNDINGCOORDINATE	-58.4177095990599
WESTBOUNDINGCOORDINATE	-85.5363614515652
NORTHBOUNDINGCOORDINATE	-11.9871990497647
SOUTHBOUNDINGCOORDINATE	-33.0740234458278
Orbit Calculated Spatial Domain	
ORBITNUMBER.1	6149
EQUATORCROSSINGLONGITUDE.1	-66.1949490630604
EQUATORCROSSINGDATE.1	2001-02-12
EQUATORCROSSINGTIME.1	15:06:12.273251
Measured Parameter	
PARAMETERNAME.1	"Cloud_Top_Pressure" (example)
SCIENCEQUALITYFLAG.1	"Not Investigated"
SCIENCEQUALITYFLAGEXPLANATION.1	"See http://modis-atmos.gsfc.nasa.gov/validation.html for more details on MODIS Atmosphere data quality."
AUTOMATICQUALITYFLAG.1	"Passed"
AUTOMATICQUALITYFLAGEXPLANATION.1	"Passed: >10% useable; Failed: <10% useable"
QAPERCENTMISSINGDATA.1 #	23

† MODIS product input files # Pertains to Measured ParameterName and refers to 23% of granule being clear (no CTP retrieval)

QA Inventory Metadata

In addition to the ECS (or Core) Inventory Metadata described above, product-specific **QA Inventory Metadata** is used to accommodate the QA needs of each specific Level 2 (only) MODIS Atmosphere product. There is no QA Inventory Metadata defined or stored for Level 3 Atmosphere products.

The QA Inventory Metadata includes statistics reported by either the MODIS cloud mask algorithm or by the product generation algorithm itself. For all L2 MODIS atmosphere products, the QA Inventory Metadata may include:

- % successful rate of retrieval
- % low confidence clear sky
- % various cloud types
- % non-cloud obstruction
- % day processed
- % night processed
- maximum solar zenith angle
- minimum solar zenith angle
- % land processed
- % water processed
- % snow background processed
- % shadow processed
- % sunglint processed

An important feature of QA Inventory Metadata is its searchability. A user can skip an entire granule of data if the requested criteria are not satisfied, or can examine the granule in more detail if criteria are satisfied. Detailed descriptions of product-specific QA Inventory Metadata for each MODIS Atmosphere product follows.

Aerosol Product: MOD04_L2 (Terra) & MYD04_L2 (Aqua)

QA Inventory Metadata

(Note: Denominator in all Percentages = Total Pixels in entire Granule)

Field Name	Field Description	Sample Value ^
Aerosol Retrieval		
AdditionalAttributeName.1	SuccessfulRetrievalPct_Land [1]	9.10
AdditionalAttributeName.2	SuccessfulRetrievalPct_Ocean [2]	15.77
Cloud and Non Cloud Obstructions		
AdditionalAttributeName.3	LowConfidentClearPct [m]	69.15
AdditionalAttributeName.11	ThinCirrusSolarFoundPct [m]	22.56
AdditionalAttributeName.12	ThinCirrusIR_FoundPct [m]	3.48
AdditionalAttributeName.13	NonCloudObstructionFoundPct [m]	0.25
Day/Night		
AdditionalAttributeName.4	DayProcessedPct [m]	100.00
AdditionalAttributeName.5	NightProcessedPc [m]	0.00
Solar Zenith Angle		
AdditionalAttributeName.14	MaxSolarZenithAngle[m]	40.53
AdditionalAttributeName.15	MinSolarZenithAngle[m]	14.10
Scene Surface Type		
AdditionalAttributeName.8	LandProcessedPct [m]	51.99
AdditionalAttributeName.9	WaterProcessedPct [m]	48.01
AdditionalAttributeName.7	Snow_IceSurfaceProcessPct [m]	0.00
AdditionalAttributeName.10	ShadowFoundPct [m]	0.08
AdditionalAttributeName.6	SunglintProcessPct [m, i]	48.07

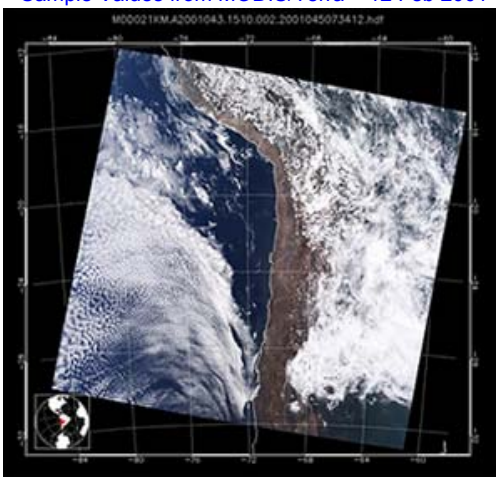
[1] For the Aerosol over Land algorithm, only clear-sky, dark-surface land pixels are retrieved.

[2] For the Aerosol over Ocean algorithm, only clear-sky, non-glint ocean pixels are retrieved.

[m] Fields are COPIED from the Cloud Mask QA Inventory Metadata and apply to a 1x1 km resolution analysis of granule.

[i] Incorrectly computed (based on solar and viewing geometry only -- did not consider whether the pixel is over land or water).

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Water Vapor Product: MOD05_L2 (Terra) & MYD05_L2 (Aqua)

QA Inventory Metadata

(Note: Denominator in all Percentages = Total Pixels in entire Granule)

Field Name	Field Description	Sample Value ^
Water Vapor Retrieval		
AdditionalAttributeName.1	SuccessfulRetrievalPct_NIR [1]	99.62
AdditionalAttributeName.2	SuccessfulRetrievalPct_IR [2]	30.75
Cloud and Non Cloud Obstructions		
AdditionalAttributeName.3	LowConfidentClearPct [m]	69.15
AdditionalAttributeName.11	ThinCirrusSolarFoundPct [m]	22.56
AdditionalAttributeName.12	ThinCirrusIR_FoundPct [m]	3.48
AdditionalAttributeName.13	NonCloudObstructionFoundPct [m]	0.25
Day/Night		
AdditionalAttributeName.4	DayProcessedPct [m]	100.00
AdditionalAttributeName.5	NightProcessedPct [m]	0.00
Solar Zenith Angle		
AdditionalAttributeName.14	MaxSolarZenithAngle [m]	40.53
AdditionalAttributeName.15	MinSolarZenithAngle [m]	14.10
Scene Surface Type		
AdditionalAttributeName.8	LandProcessedPct [m]	51.99
AdditionalAttributeName.9	WaterProcessedPct [m]	48.01
AdditionalAttributeName.7	Snow_IceSurfaceProcessPct [m]	0.00
AdditionalAttributeName.10	ShadowFoundPct [m]	0.08
AdditionalAttributeName.6	SunglintProcessPct [m, i]	48.07

[1] For the Near IR Water Vapor algorithm, all non-missing pixels are retreived (but only bright-land & ocean-glint pixels are reliable).

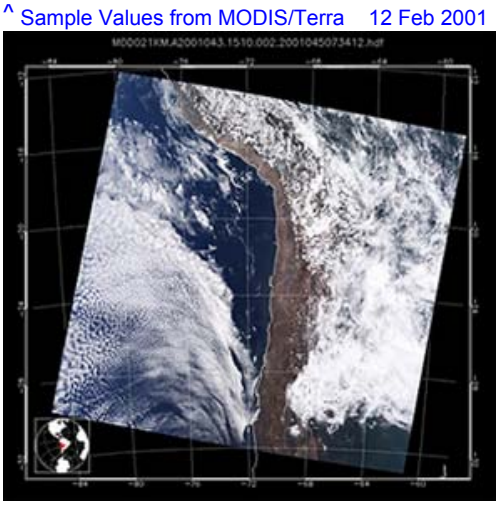
Collection 006 Suggestion: Fix SuccessfulRetrievalPct_NIR computation so the numerator = "reliable (useful) retrievals only".

[2] For the IR Water Vapor algorithm, only clear-sky pixels (over both land and ocean) are retreived.

[m] Fields are COPIED from the Cloud Mask QA Inventory Metadata and apply to a 1x1 km resolution analysis of granule.

[i] Incorrectly computed (based on solar and viewing geometry only -- did not consider whether the pixel is over land or water).

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Cloud Product: MOD06_L2 (Terra) & MYD06_L2 (Aqua)

QA Inventory Metadata

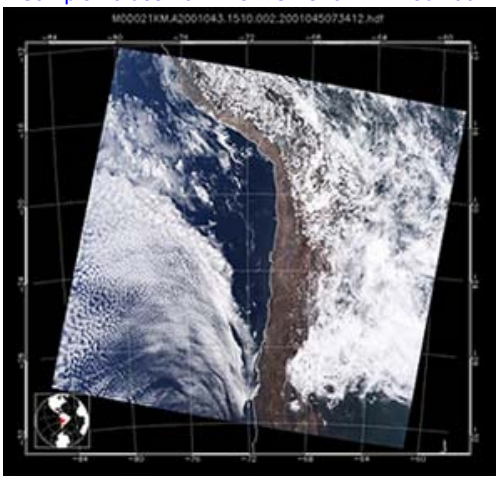
(Note: Denominator in all Percentages = Total Pixels in entire Granule)

Field Name	Field Description	Sample Value ^
Cloud Top Property Retrieval		
AdditionalAttributeName.1	SuccessCloudTopPropRtrPct_IR [1]	77.12
AdditionalAttributeName.2	SuccessCloudPhaseRtrPct_IR [1]	76.75
AdditionalAttributeName.4	LowCloudDetectedPct_IR	19.77
AdditionalAttributeName.5	MidCloudDetectedPct_IR	38.91
AdditionalAttributeName.6	HighCloudDetectedPct_IR	18.44
AdditionalAttributeName.8	ThickCloudDetectedPct_IR	28.21
AdditionalAttributeName.7	ThinCloudDetectedPct_IR	6.44
AdditionalAttributeName.9	OpaqueCloudDetectedPct_IR	42.47
AdditionalAttributeName.10	CirrusCloudDetectedPct_IR	34.65
AdditionalAttributeName.12	WaterCloudDetectedPct_IR	49.69
AdditionalAttributeName.11	IceCloudDetectedPct_IR	13.05
AdditionalAttributeName.13	MixedCloudDetectedPct_IR	4.86
AdditionalAttributeName.14	CloudPhaseUncertainPct_IR	9.15
Cloud Optical Property Retrieval		
AdditionalAttributeName.3	SuccessCloudOptPropRtrPct_VIS *(succsesful retrievals only)*	64.32
AdditionalAttributeName.18	CloudCoverFractionPct_VIS *(successful & unsuccessful)*	67.56
AdditionalAttributeName.19	WaterCloudDectectedPct_VIS *(successful & unsuccessful)*	45.54
AdditionalAttributeName.20	IceCloudDetectedPct_VIS *(successful & unsuccessful)*	20.86
Scene Surface Type		
AdditionalAttributeName.16	LandCoverFractionPct [m]	51.99
AdditionalAttributeName.15	OceanCoverFractionPct [m]	48.01
AdditionalAttributeName.17	SnowCoverFractionPct [m]	0.00

[1] Only 5x5 km grids determined to be cloudy are retrieved. CTP algorithms "detect" more clouds than Cloud Mask and Optical Prop. algorithms due to 5x5 avg'ing. CloudTopPropertyIR and CloudPhaseIR pcts. are different due to different bands being used.

[m] Fields are COPIED from the Cloud Mask QA Inventory Metadata and apply to a 1x1 km resolution analysis of granule.

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Atmospheric Profile Product: MOD07_L2 (Terra) & MYD07_L2 (Aqua)

QA Inventory Metadata

(Note: Denominator in all Percentages = Total Pixels in entire Granule)

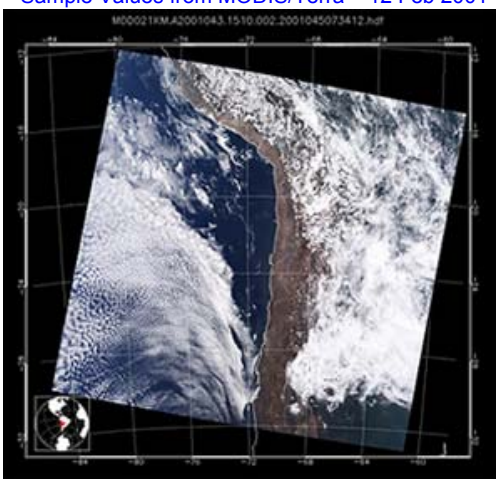
Field Name	Field Description	Sample Value ^
Atmospheric Profile Retrieval		
AdditionalAttributeName.1	SuccessfulRetrievalPct [1]	30.75
Cloud and Non Cloud Obstructions		
AdditionalAttributeName.2	LowConfidenceClearPct [m]	69.15
AdditionalAttributeName.10	ThinCirrusSolarFoundPct [m]	22.56
AdditionalAttributeName.11	ThinCirrusIR_FoundPct [m]	3.48
AdditionalAttributeName.12	NonCloudObstructionFoundPct [m]	0.25
Day/Night		
AdditionalAttributeName.3	DayProcessedPct [m]	100.00
AdditionalAttributeName.4	NightProcessedPct [m]	0.00
Solar Zenith Angle		
AdditionalAttributeName.13	MaxSolarZenithAngle [m]	40.53
AdditionalAttributeName.14	MinSolarZenithAngle [m]	14.10
Scene Surface Type		
AdditionalAttributeName.7	LandProcessedPct [m]	51.99
AdditionalAttributeName.8	WaterProcessedPct [m]	48.01
AdditionalAttributeName.6	Snow_IceSurfaceProcessPct [m]	0.00
AdditionalAttributeName.9	ShadowFoundPct [m]	0.08
AdditionalAttributeName.5	SunglintProcessPct [m, i]	48.07

[1] For the Atmospheric Profiles algorithm, only clear-sky pixels (either land or ocean) are retreived.

[m] Fields are COPIED from the Cloud Mask QA Inventory Metadata and apply to a 1x1 km resolution analysis of granule.

[i] Incorrectly computed (based on solar and viewing geometry only -- did not consider whether the pixel is over land or water).

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Cloud Mask Product: MOD35_L2 (Terra) & MYD35_L2 (Aqua)

QA Inventory Metadata

(Note: Denominator in all Percentages = Total Pixels in entire Granule)

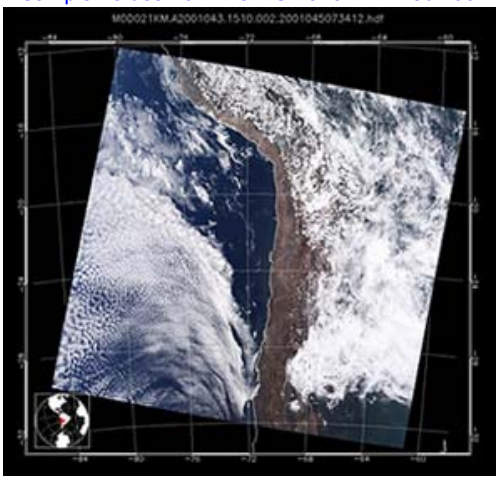
Field Name	Field Description	Sample Value ^
Cloud Mask Retrieval		
AdditionalAttributeName.1	SuccessfulRetrievalPct [1]	100.00
Cloud and Non Cloud Obstructions		
AdditionalAttributeName.7	ClearPct250m	34.90
AdditionalAttributeName.6	CloudCoverPct250m	65.10
AdditionalAttributeName.2	VeryHighConfidenceClearPct	23.78
AdditionalAttributeName.3	HighConfidenceClearPct	5.09
AdditionalAttributeName.4	UncertainConfidentClearPct	1.98
AdditionalAttributeName.5	LowConfidentClearPct	69.15
AdditionalAttributeName.15	ThinCirrusSolarFoundPct	22.56
AdditionalAttributeName.16	ThinCirrusIR_FoundPct	3.48
AdditionalAttributeName.17	NonCloudObstructionFoundPct	0.25
Day/Night		
AdditionalAttributeName.8	DayProcessedPct	100.00
AdditionalAttributeName.9	NightProcessedPct	0.00
Solar Zenith Angle		
AdditionalAttributeName.18	MaxSolarZenithAngle	40.53
AdditionalAttributeName.19	MinSolarZenithAngle	14.10
Scene Surface Type		
AdditionalAttributeName.12	LandProcessedPct	51.99
AdditionalAttributeName.13	WaterProcessedPct	48.01
AdditionalAttributeName.11	Snow_IceSurfaceProcessPct	0.00
AdditionalAttributeName.14	ShadowFoundPct	0.08
AdditionalAttributeName.10	SunglintProcessPct [i]	48.07

[1] For the Cloud Mask algorithm, all non-missing L1B pixels are retrieved.

[i] Incorrectly computed (based on solar and viewing geometry only -- did not consider whether the pixel is over land or water).

Collection 006 Suggestion: Fix the SunglintProcessPct computation (noted above). Fix will propagate to other L2 products.

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Joint Atmosphere Product: MODATML2 (Terra) & MYDATML2 (Aqua)

QA Inventory Metadata

(Note: Denominator in all Percentages = Total Pixels in entire Granule)

Field Name	Field Description	Sample Value ^
Aerosol Retrieval		
AdditionalAttributeName.18	SuccessfulRetrievalPct_Land [1]	9.10
AdditionalAttributeName.19	SuccessfulRetrievalPct_Ocean [2]	15.77
Water Vapor Retrieval		
AdditionalAttributeName.20	SuccessfulRetrievalPct_NIR [3]	99.62
AdditionalAttributeName.21	SuccessfulRetrievalPct_IR [4]	30.75
Cloud Top Property Retrieval		
AdditionalAttributeName.22	SuccessCloudTopPropRtrPct_IR [5]	77.12
AdditionalAttributeName.23	SuccessCloudPhaseRtrPct_IR [5]	76.75
Cloud Optical Property Retrieval		
AdditionalAttributeName.24	SuccessCloudOptPropRtrPct_VIS *(succsesful retrievals only)*	64.32
AdditionalAttributeName.25	CloudCoverFractionPct_VIS *(successful & unsuccessful)*	67.56
AdditionalAttributeName.26	WaterCloudDectectedPct_VIS *(successful & unsuccessful)*	45.54
AdditionalAttributeName.27	IceCloudDetectedPct_VIS *(successful & unsuccessful)*	20.86
Cloud Mask Retrieval		
AdditionalAttributeName.1	SuccessfulRetrievalPct [m]	100.00
Cloud and Non Cloud Obstructions		
AdditionalAttributeName.12	VeryHighConfidentClearPct [m]	23.78
AdditionalAttributeName.13	HighConfidentClearPct [m]	5.09
AdditionalAttributeName.14	UncertainConfidentClearPct [m]	1.98
AdditionalAttributeName.15	LowConfidentClearPct [m]	69.15
AdditionalAttributeName.16	ThinCirrusSolarFoundPct [m]	22.56
AdditionalAttributeName.17	ThinCirrusIR_FoundPct [m]	3.48
AdditionalAttributeName.9	NonCloudObstructionFoundPct [m]	0.25
Day/Night		
AdditionalAttributeName.2	DayProcessedPct [m]	100.00
AdditionalAttributeName.3	NightProcessedPct [m]	0.00
Solar Zenith Angle		
AdditionalAttributeName.10	MaxSolarZenithAngle [m]	40.53
AdditionalAttributeName.11	MinSolarZenithAngle [m]	14.10
Scene Surface Type		
AdditionalAttributeName.4	LandProcessedPct [m]	51.99
AdditionalAttributeName.5	WaterProcessedPct [m]	48.01
AdditionalAttributeName.6	Snow_IceSurfaceProcessedPct [m]	0.00
AdditionalAttributeName.7	ShadowFoundPct [m]	0.08
AdditionalAttributeName.8	SunglintProcessedPct [m, i]	48.07

[1] For Aerosol over Land algorithm, only clear-sky, dark-surface land pixels are retrieved.

[2] For Aerosol over Ocean algorithm, only clear-sky, non-glint ocean pixels are retrieved.

[3] For Near IR Water Vapor, all non-missing pixels are retreived (but only bright-land & ocean-glint pixels are reliable).

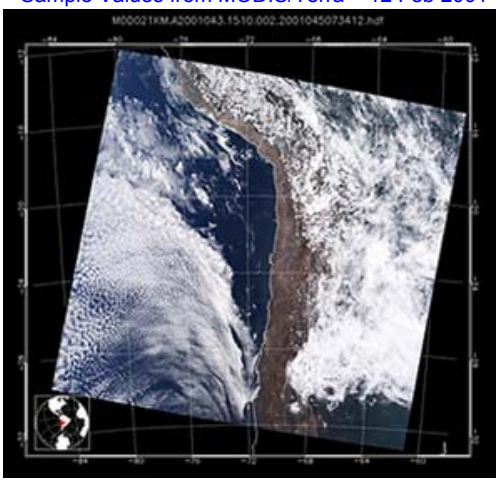
[4] For IR Water Vapor, only clear-sky pixels (land and ocean) are retreived. (Note: This number matches Atm Profile SuccessPct).

[5] Only 5x5 km grids determined to be cloudy are retrieved. CTP algorithms “detect” more clouds than Cloud Mask and Optical Prop. algorithms due to 5x5 avg’ing. CloudTopPropertyIR and CloudPhaseIR pcts. are different due to different bands being used.

[m] Fields are COPIED from the Cloud Mask QA Inventory Metadata and apply to a 1x1 km resolution analysis of granule.

[i] Incorrectly computed (based on solar and viewing geometry only -- did not consider whether the pixel is over land or water).

^ Sample Values from MODIS/Terra 12 Feb 2001 15:10



Appendix C:

Archive Metadata

of

Atmosphere Products

Introduction

This appendix describes the Archive Metadata for all MODIS Atmosphere products. Archive Metadata, stored in the HDF global attribute "ArchiveMetadata.0", are designed to report summary statistics and information pertaining to a granule for documentation purposes only.

Archive metadata is stored (archived) along with science data sets of each granule. These values are not searchable. Archive Metadata is defined in both Level 2 and Level 3 MODIS Atmosphere products.

Arguably, the two most useful pieces of information in the Archive Metadata are the *LocalInputGranuleID* and *ProductionHistory* strings.

- The *LocalInputGranuleID* contains a full list of input files used to create the HDF product file in question. Input files can include other MODIS HDF product files (typically L1B Calibrated Radiances and/or L2 Cloud Mask) and additional ancillary files (such as algorithm specific look-up libraries, and/or snow, albedo and ecosystem maps) needed to run the L2 product algorithm.

- The *ProductionHistory* contains the program executable (PGE) version that was used to produce the HDF product file. This allows users to trace the maturity and quality of HDF data products. Specific changes incorporated into various versions of PGEs can be found in the Products section of the MODIS Atmosphere web site at http://modis-atmos.gsfc.nasa.gov/products_calendar_pge03.html (Note that the link specified is for PGE03, which produces the Cloud Mask and Atmospheric Profiles products. All other MODIS Atmosphere PGE's can be selected through the menu on the left hand side of this page).

The complete set of archive metadata for each MODIS Atmosphere product is described below.

Aerosol Product: MOD04_L2 (Terra) & MYD04_L2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Aerosol 5-Min L2 Swath 10km"
PROCESSINGENVIRONMENT	"Linux minion5027 2.4.20-37.7.legacysmp #1 SMP Mon Sep 27 21:38:15 EDT 2004 i686 unknown"
ALGORITHMPACKAGEACCEPTANCE DATE	"June-1997"
ALGORITHMPACKAGEMATURITYCODE	"at-launch"
ALGORITHMPACKAGENAME #	"ATBD-MOD-02"
ALGORITHMPACKAGEVERSION	"2"
INSTRUMENTNAME	"Moderate Resolution Imaging Spectroradiometer"
LOCALINPUTGRANULEID †	"MOD03.A2001043.1510.005.2005105143551.hdf, MOD021KM.A2001043.1510.005.2005105163716.hdf, MOD35_L2.A2001043.1510.005.2005105171245.hdf"
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
VERYGOODQUALITYDATAPCT_LAND	0.00
GOODQUALITYDATAPCT_LAND	100.00
MARGINALQUALITYDATAPCT_LAND	0.00
BADQUALITYDATAPCT_LAND	0.00
VERYGOODQUALITYDATAPCT_OCEAN	64.65
GOODQUALITYDATAPCT_OCEAN	3.80
MARGINALQUALITYDATAPCT_OCEAN	15.96
BADQUALITYDATAPCT_OCEAN	17.00
ALGORITHMSOFTWAREVERSIONLAND	2
ALGORITHMSOFTWAREVERSIONOCEAN	2
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE04:5.1.0

Refers to Algorithm Theoretical Basis Document (ATBD) reference number

† MODIS product input files

Water Vapor Product: MOD05_L2 (Terra) & MYD05_L2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Total Precipitable Water Vapor 5-Min L2 Swath 1km and 5km"
PROCESSINGENVIRONMENT	"Linux minion5027 2.4.20-37.7.legacysmp #1 SMP Mon Sep 27 21:38:15 EDT 2004 i686 unknown"
ALGORITHMPACKAGEACCEPTANCEDATE	"June 1997"
ALGORITHMPACKAGEMATURITYCODE	"at-launch"
ALGORITHMPACKAGENAME #	"ATBD-MOD-03"
ALGORITHMPACKAGEVERSION	"2"
INSTRUMENTNAME	"Moderate Resolution Imaging Spectroradiometer"
LOCALINPUTGRANULEID †	"MOD03.A2001043.1510.005.2005105143551.hdf, MOD021KM.A2001043.1510.005.2005105163716.hdf, MOD35_L2.A2001043.1510.005.2005105171245.hdf, MOD07_L2.A2001043.1510.005.2005105171354.hdf"
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
ALGORITHMSOFTWAREVERSION_NIR	2
ALGORITHMSOFTWAREVERSION_IR	2
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE04:5.1.0

Refers to Algorithm Theoretical Basis Document (ATBD) reference number

† MODIS product input files

Cloud Product: MOD06_L2 (Terra) & MYD06_L2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Clouds 5-Min L2 Swath 1km and 5km"
PROCESSINGENVIRONMENT	"Linux minion5027 2.4.20-37.7.legacysmp #1 SMP Mon Sep 27 21:38:15 EDT 2004 i686 unknown"
ALGORITHMPACKAGEACCEPTANCE DATE	"June-1997"
ALGORITHMPACKAGEMATURITYCODE	"at-launch"
ALGORITHMPACKAGENAME #	"ATBD-MOD-04 and ATBD-MOD-05"
ALGORITHMPACKAGEVERSION	2
INSTRUMENTNAME	"Moderate Resolution Imaging Spectroradiometer"
LOCALINPUTGRANULEID †	"MOD021KM.A2001043.1510.005.2005105163716.hdf, MOD03.A2001043.1510.005.2005105143551.hdf, MOD35_L2.A2001043.1510.005.2005105171245.hdf, Library_water.hdf.v1, Library_ice.hdf.v2, Transmittance.hdf.v2, AlbMap.WS.vb1.0.2001.033.0.659.hdf, AlbMap.WS.vb1.0.2001.033.0.858.hdf, AlbMap.WS.vb1.0.2001.033.1.24.hdf, AlbMap.WS.vb1.0.2001.033.1.64.hdf, AlbMap.WS.vb1.0.2001.033.2.13.hdf, AlbSnwSts.ByNISE.W90.D90.WS.Lats.70.40.2000-2004.Oct.Jan.hdf, IGBP.EcoMap.NtoS.2004.149.v004.hdf"
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
ALGORITHM_VERSION_CLOUD_TOP_PROPERTY_IR	1
ALGORITHM_VERSION_CLOUD_PHASE_IR	1
ALGORITHM_VERSION_CLOUD_PROPERTY_VIS	1
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE06:5.3.0

Refers to Algorithm Theoretical Basis Document (ATBD) reference number

† MODIS product input files

Atmospheric Profile Product: MOD07_L2 (Terra) & MYD07_L2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Temperature and Water Vapor Profiles 5-Min L2 Swath 5km"
PROCESSINGENVIRONMENT	""Linux minion352 2.4.18-27.7.xsmp #1 SMP Fri Mar 14 05:52:30 EST 2003 i686 unknown""
INSTRUMENTNAME	"Moderate Resolution Imaging Spectroradiometer"
ALGORITHMPACKAGEACCEPTANCE DATE	"June 1997"
ALGORITHMPACKAGEMATURITYCODE	"at-launch"
ALGORITHMPACKAGENAME #	"ATBD-MOD-07"
ALGORITHMPACKAGEVERSION	"2"
LOCALINPUTGRANULEID †	""MOD021KM.A2001043.1510.005.2005105163716.hdf, MOD03.A2001043.1510.005.2005105143551.hdf, MOD35_L2.A2001043.1510.005.2005105171245.hdf, gdas1.PGrbF00.010212.18z, MODIS_REGCOEF_FACTORS.terra.v5, MODIS_senzen.bin, terra_bias.dat.v2, terra_det.dat.v2""
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
PROFILES_ALGORITHM_VERSION_NUMBER	1
STABILITY_INDICES_ALGORITHM_VERSION_NUMBER	1
TOTAL_OZONE_ALGORITHM_VERSION_NUMBER	1
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE03:5.1.5

Refers to Algorithm Theoretical Basis Document (ATBD) reference number

† MODIS product input files

Cloud Mask Product: MOD35_L2 (Terra) & MYD35_L2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Cloud Mask and Spectral Test Results 5-Min L2 Swath 250m and 1km"
PROCESSINGENVIRONMENT	""Linux minion352 2.4.18-27.7.xsmp #1 SMP Fri Mar 14 05:52:30 EST 2003 i686 unknown""
INSTRUMENTNAME	""Moderate Resolution Imaging Spectroradiometer"
ALGORITHMPACKAGEACCEPTANCE DATE	"June-1997"
ALGORITHMPACKAGEMATURITYCODE	"at-launch"
ALGORITHMPACKAGENAME #	"ATBD-MOD-06"
ALGORITHMPACKAGEVERSION	"2"
LOCALINPUTGRANULEID †	""MOD03.A2001043.1510.005.2005105143551.hdf, MOD021KM.A2001043.1510.005.2005105163716.hdf, MOD02QKM.A2001043.1510.005.2005105163716.hdf, goge1_2_img.v1, ecosystem.img.v1, thresholds.dat.terra.v13, gdas1.PGrbF00.010212.18z, oisst.20010214, eng.010213, NISE_SSMIF13_20010212.HDFEOS"
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
CLOUD_MASK_ALGORITHM_VERSION_NUMBER	1.00
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE03:5.1.5

Refers to Algorithm Theoretical Basis Document (ATBD) reference number

† MODIS product input files

Joint Atmosphere Product: MODATML2 (Terra) & MYDATML2 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Aerosol, Cloud and Water Vapor Subset 5-Min L2 Swath 5km and 10km"
PROCESSINGENVIRONMENT	"Linux minion5027 2.4.20-37.7.legacysmp #1 SMP Mon Sep 27 21:38:15 EDT 2004 i686 unknown"
INSTRUMENTNAME	"Moderate Resolution Imaging Spectroradiometer"
EXCLUSIONGRINGFLAG	"N"
GRINGPOINTLATITUDE	(-11.9657643150703, -15.1127398445589, -33.2616100115919, -29.5206668804633)
GRINGPOINTLONGITUDE	(-79.8034155352806, -58.1828178475367, -61.0282026524014, -85.5445842551903)
GRINGPOINTSEQUENCENO	(1, 2, 3, 4)
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE83:5.1.0

Collection 006 Suggestions:

1.) Include a string of PGE's (reflecting the L2 MODIS Atmosphere input products), as was done for L3 (e.g., PRODUCTIONHISTORY = "PGE03:5.1.5; PGE06:5.3.0; PGE04:5.1.0; PGE83:5.1.0")

2.) Add LocalInputGranuleID string and populate with the four L2 MODIS Atmosphere input product HDF file names, as is done for all other products. (Note that "InputPointer" in ECS (Core) Inventory Metadata duplicates this info.)

Daily Global Product: MOD08_D3 (Terra) & MYD08_D3 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Aerosol Cloud Water Vapor Ozone Daily L3 Global 1Deg CMG"
PROCESSINGENVIRONMENT	"IRIX64 mtvs2 6.5 10070055 IP35"
LOCALINPUTGRANULEID	†
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE03:5.1.5;PGE06:5.3.0;PGE04:5.1.0;PGE69:5.1.1;PGE56:5.1.1

† MODIS product input files (nearly 1200 L2 MODIS HDF file names)

Eight Day Global Product: MOD08_E3 (Terra) & MYD08_E3 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Aerosol Cloud Water Vapor Ozone Eight Day L3 Global 1Deg CMG"
PROCESSINGENVIRONMENT	"IRIX64 mtvs2 6.5 10070055 IP35"
LOCALINPUTGRANULEID	†
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE03:5.1.5;PGE06:5.3.0;PGE04:5.1.0;PGE69:5.1.1;PGE56:5.1.1;PGE70:5.1.0

† MODIS product input files (up to 8 L3 Daily MODIS HDF file names)

Monthly Global Product: MOD08_M3 (Terra) & MYD08_M3 (Aqua)

Archive Metadata

Field name	Sample Value
LONGNAME	"MODIS/Terra Aerosol Cloud Water Vapor Ozone Monthly L3 Global 1Deg CMG"
PROCESSINGENVIRONMENT	"IRIX64 mtvs2 6.5 10070055 IP35"
LOCALINPUTGRANULEID	†
DESCRREVISION	5.0
PRODUCTIONHISTORY	PGE03:5.1.5;PGE06:5.3.0;PGE04:5.1.0;PGE69:5.1.1;PGE56:5.1.1;PGE57:5.1.0

† MODIS product input files (up to 31 L3 Daily MODIS HDF file names)