**MOD04\_L2 Product Info**

**From http://modis-atmos.gsfc.nasa.gov/**

Introduction  
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**Product Description**

The MODIS Aerosol Product monitors the ambient aerosol optical thickness over the oceans globally and over a portion of the continents. Further, the aerosol size distribution is derived over the oceans, and the aerosol type is derived over the continents. Daily Level 2 data are produced at the spatial resolution of a 10x10 1-km (at nadir)-pixel array. There are two MODIS Aerosol data product files: **MOD04\_L2**, containing data collected from the Terra platform; and **MYD04\_L2**, containing data collected from the Aqua platform.

**Research and Application**

Aerosols are one of the greatest sources of uncertainty in climate modeling. Aerosols vary in time in space and can lead to variations in cloud microphysics, which could impact cloud radiative properties and climate. The MODIS aerosol product is used to study aerosol climatology, sources and sinks of specific aerosol types (e.g., sulfates and biomass-burning aerosol), interaction of aerosols with clouds, and atmospheric corrections of remotely sensed surface reflectance over the land.

**Data Set Evolution**

Prior to MODIS, satellite measurements were limited to reflectance measurements in one (GOES, METEOSAT) or two (AVHRR) channels. There was no real attempt to retrieve aerosol content over land on a global scale. Algorithms had been developed for use only over dark vegetation. The blue channel on MODIS, not present on AVHRR, offers the possibility to extend the derivation of optical thickness over land to additional surfaces. The algorithms will use MODIS bands 1 through 7 and 20 and require prior cloud screening using MODIS data. Over the land, the dynamic aerosol models will be derived from ground-based sky measurements and used in the net retrieval process.

Over the ocean, three parameters that describe the aerosol loading and size distribution will be retrieved. Pre-assumptions on the general structure of the size distribution are required in the inversion of MODIS data, and the volume-size distribution will be described with two log-normal modes: a single mode to describe the accumulation mode particles (radius < 0.5 µm) and a single coarse mode to describe dust and/or salt particles (radius > 1.0 µm). The aerosol parameters we therefore expect to retrieve are: the ratio between the two modes, the spectral optical thickness, and the mean particle size.

The quality control of these products will be based on comparison with ground stations and climatology.

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Format & Content  
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**File Format Basics**

MOD04\_L2 product files are stored in Hierarchical Data Format (HDF). HDF is a multi-object file format for sharing scientific data in multi-platform distributed environments. HDF files should only be accessed through HDF library subroutine and function calls, which can be downloaded from the [HDF web site](http://hdf.ncsa.uiuc.edu" \t "New)\*. Each of the 53 gridded parameters listed below is stored as a Scientific Data Set (SDS) within the HDF file.

\* NOTE: MATLAB provides an HDF toolbox which allows the user to read HDF files content. There are other softwares that can be downloaded from the NASA web sites to view and display this type of files.

**MOD04\_L2 Dimension List**

1. Cell\_Along\_Swath = 203 (typical size)
2. Cell\_Across\_Swath = 135 (typical size)
3. Solution\_1\_Land = 2
4. Solution\_2\_Land = 3
5. Solution\_3\_Land = 3
6. Solution\_Ocean = 2
7. MODIS\_Band\_Land = 7
8. MODIS\_Band\_Ocean = 7
9. QA\_Byte\_Land = 5
10. QA\_Byte\_Ocean = 5
11. Solution\_Index = 9
12. Number\_of\_Instrument\_Scans = 203 (typical size)
13. Maximum\_Number\_of\_1km\_Frames = 1354 (typical size)

**MOD04\_L2 Scientific Data Set (SDS) List**

Geolocation and Time Parameters

1. Longitude

Description: Geodetic Longitude   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -180 to +180 degrees east

1. Latitude

Description: Geodetic Latitude   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -90 to +90 degrees north

1. Scan\_Start\_Time

Description: International Atomic Time at Start of Scan replicated across the Swath   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0.0 to 3.1558E+9 seconds since 1 January 1993 00:00:00

Solar and Viewing Geometry Parameters

1. Solar\_Zenith

Description: Solar Zenith Angle, Cell to Sun   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to +180 degrees

1. Solar\_Azimuth

Description: Solar Azimuth Angle, Cell to Sun   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -180 to +180 degrees

1. Sensor\_Zenith

Description: Sensor Zenith Angle, Cell to Sensor   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 180 degrees

1. Sensor\_Azimuth

Description: Sensor Azimuth Angle, Cell to Sensor   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -180 to 180 degrees

Science Parameters

Combined Land and Ocean

1. Scattering\_Angle

Description: Scattering Angle   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 180 degrees

1. Optical\_Depth\_Land\_And\_Ocean

Description: Aerosol Optical Thickness at 0.55 µm for both Ocean (best) and Land (corrected)   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

Land Only

1. Aerosol\_Type\_Land

Description: Aerosol Type   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 4    *(0=mixed, 1=dust, 2=sulfate, 3=smoke, 4=heavy absorbing smoke)*

1. Continental\_Optical\_Depth\_Land

Description: Continental Optical Thickness at 0.47 and 0.66 µm   
Dimensions: (Solution\_1\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Corrected\_Optical\_Depth\_Land

Description: Corrected Optical Thickness at 0.47, 0.55, and 0.66 µm   
Dimensions: (Solution\_2\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Estimated\_Uncertainty\_Land

Description: Uncertainty of Optical Thickness at 0.47 and 0.66 µm   
Dimensions: (Solution\_1\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 2

1. Mass\_Concentration\_Land

Description: Mass Concentration over Land   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1000 x 1.0e-6g/cm^2

1. Angstrom\_Exponent\_Land

Description: Angstrom Exponent at 0.47 and 0.67 µm   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -0.5 to 3

1. Reflected\_Flux\_Land

Description: Normalized Reflected Flux at 0.47 and 0.66 µm   
Dimensions: (Solution\_1\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Transmitted\_Flux\_Land

Description: Normalized Transmitted Flux at 0.47 and 0.66 µm   
Dimensions: (Solution\_1\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Cloud\_Fraction\_Land

Description: Cloud Fraction (%)   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 100%

1. Dust\_Weighting\_Factor\_Land

Description: Dust Aerosol Weighting Factor   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Number\_Pixels\_Percentile\_Land

Description: Number of Pixels in Desired Percentile   
Dimensions: (Solution\_1\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 400

1. Mean\_Reflectance\_Land

Description: Mean Reflectance at 5 bands   
Dimensions: (MODIS\_Band\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. STD\_Reflectance\_Land

Description: Standard Deviation of Reflectance at 5 bands   
Dimensions: (MODIS\_Band\_Land, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 2

Ocean Only

1. Solution\_Index\_Ocean\_Small

Description: Solution number index (1 through 4) for small aerosol particles (for best and average solutions). Indices of ocean models 1 through 4 correspond to accumulation (small) mode models with effective radii 0.10, 0.15, 0.20, 0.25 µm, respectively.   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 1 to 5

1. Solution\_Index\_Ocean\_Large

Description: Solution number index (5 through 9) for large aerosol particles (for best and average solutions). Indices of ocean models 5 through 7 correspond to coarse (large) mode models of marine (sea salt) particles with effective radii 1.0, 1.5, 2.0 µm, respectively. Indices of ocean models 8 and 9 correspond to coarse (large) mode models of mineral dust particles with effective radii 1.5 and 2.5 µm, respectively.   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 6 to 11

1. Effective\_Optical\_Depth\_Best\_Ocean

Description: Aerosol Optical Thickness for Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Effective\_Optical\_Depth\_Average\_Ocean

Description: Aerosol Optical Thickness for Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Optical\_Depth\_Small\_Best\_Ocean

Description: Aerosol Optical Thickness for Small Mode of Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Optical\_Depth\_Small\_Average\_Ocean

Description: Aerosol Optical Thickness for Small Mode of Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Optical\_Depth\_Large\_Best\_Ocean

Description: Aerosol Optical Thickness for Large Mode of Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Optical\_Depth\_Large\_Average\_Ocean

Description: Aerosol Optical Thickness at 7 bands for large mode of average solution   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Mass\_Concentration\_Ocean

Description: Mass Concentration for Best and Average Solutions   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1000 x 1.0e-6g/cm^2

1. Effective\_Radius\_Ocean

Description: Effective Radius of Both Solutions at 0.55 µm   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 5 µm

1. Cloud\_Condensation\_Nuclei\_Ocean

Description: Column Number of CCN of Both Solutions at 0.55 µm   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0.0 to 10000000000.0 CCN/cm^2

1. Asymmetry\_Factor\_Best\_Ocean

Description: Asymmetry Factor for Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Asymmetry\_Factor\_Average\_Ocean

Description: Asymmetry Factor for Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Backscattering\_Ratio\_Best\_Ocean

Description: Backscattering Ratio of Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Backscattering\_Ratio\_Average\_Ocean

Description: Backscattering Ratio of Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 3

1. Angstrom\_Exponent\_1\_Ocean

Description: Angstrom Exponent for 0.550 and 0.865 µm   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -0.5 to 3

1. Angstrom\_Exponent\_2\_Ocean

Description: Angstrom Exponent for 0.865 and 2.130 µm   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: -0.5 to 3

1. Reflected\_Flux\_Best\_Ocean

Description: Normalized Reflected Flux of Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Reflected\_Flux\_Average\_Ocean

Description: Normalized Reflected Flux of Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Transmitted\_Flux\_Best\_Ocean

Description: Normalized Transmitted Flux of Best Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Transmitted\_Flux\_Average\_Ocean

Description: Normalized Transmitted Flux of Average Solution at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Least\_Squares\_Error\_Ocean

Description: Least Square Error Estimate   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Small\_Mode\_Weighting\_Ocean

Description: Small Mode Weighting Factor   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Optical\_Depth\_Ratio\_Small\_Ocean

Description: Ratio of Optical Depth of Small Mode vs Effective Optical Depth at .55 µm   
Dimensions: (Solution\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. Cloud\_Fraction\_Ocean

Description: Cloud Fraction in Percentage   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 100%

1. Number\_Pixels\_Used\_Ocean

Description: Number of Pixels used for 0.55 µm solution   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 400

1. Mean\_Reflectance\_Ocean

Description: Mean Reflectances at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 1

1. STD\_Reflectance\_Ocean

Description: Standard Deviation of Reflectances at 7 bands   
Dimensions: (MODIS\_Band\_Ocean, Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: 0 to 2

Cloud Mask and QA Parameters

1. Cloud\_Mask\_QA

Description: Cloud Mask QA at 10x10 km resolution   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath)   
Valid Range: (bit mask)

1. Quality\_Assurance\_Land

Description: Run-Time QA Flags for Land   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath, QA\_Byte\_Land)   
Valid Range: (bit mask)

1. Quality\_Assurance\_Ocean

Description: Run-Time QA Flags for Ocean   
Dimensions: (Cell\_Along\_Swath, Cell\_Across\_Swath, QA\_Byte\_Ocean)   
Valid Range: (bit mask)

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Grids
 & Mapping  
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**Product Grid**

The MODIS Aerosol (MOD04\_L2) product contains data that has a spatial resolution (pixel size) of 10 x 10 kilometers (at nadir). Each MOD04\_L2 product file covers a five-minute time interval (based on the start time of each MODIS Level-1B granule), which means the MOD04\_L2 output grid is 135 10-km (at nadir) pixels in width and 203 10-km (nadir) pixels in length for nine consecutive granules. Every tenth granule has an output grid size of 135 by 204 pixels.

**Granule Coverage**

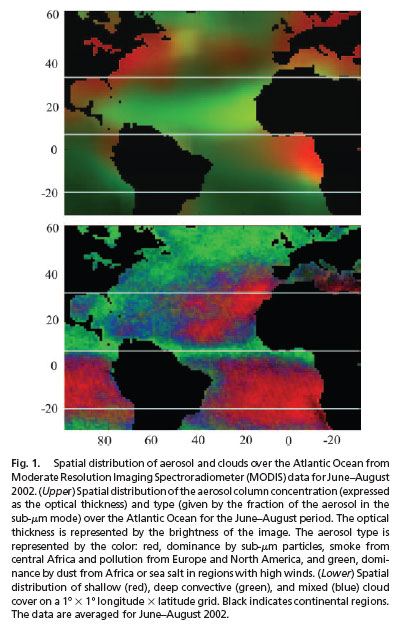
The image below depicts MODIS Level-2 granule coverage during a single simulated orbit. It should be noted that a granule of Level-2 MODIS data is defined as a single Level-2 MODIS product HDF file.

MODIS
 Level-2 Granule Coverage  
Sample
 Orbital Track and Granule Coverage  
Created 
by Li & Hubanks

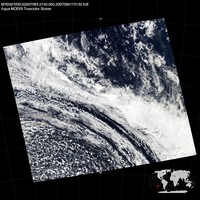
**Computation of 10-km Geolocation in L2 Atmosphere Products**

The geolocation in the 04\_L2 MODIS product is at 10-km resolution. This geolocation is generated from 10x10 1-km L1B input and is computed by averaging the 4 central (5,5), (5,6), (6,5), (6.,6) 1-km L1B input pixels in each 10x10 km area.





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Acquiring Data  
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**Sample File**

A sample (Collection 005) MYD04\_L2 HDF file (1.8MB), a fully populated daytime granule, is available for download. The image (inset) was created from the L1B radiance data for the same granule (RGB=1:4:3) 3 April 2007 at 2140 UTC. The sample HDF data file can be used to familiarize yourself with the data format and/or as input to MODIS visualization and analysis software on your local platform.

[MYD04\_L2 HDF File  
Download the HDF File](http://modis-atmos.gsfc.nasa.gov/_hdf/MYD04_L2.A2007093.2140.005.2007095201823.hdf)

**Ordering Data**

All MODIS Atmosphere data products are available to the public (at no charge) through the Level 1 and Atmosphere Archive and Distribution System (LAADS).

This new and user-friendly MODIS data ordering system gives the user convenient means to simultaneously order several MODIS Data Sets, including Geolocation. This system also works well for single products.

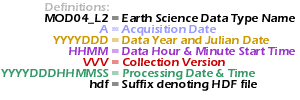
Web site: <http://ladsweb.nascom.nasa.gov/data/search.html>

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Filename Convention  
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**HDF Product File**

MODIS Level-2 Hierarchical Data Format (HDF) product files have standardized filenames. The prefix **MOD** is reserved for files containing data collected from the Terra (AM overpass) platform and **MYD** is reserved for files containing data collected from the Aqua (PM overpass) platform.

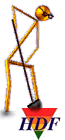
Terra (AM) Platform:   
filename1_mod04

Aqua (PM) Platform:   
filename1a_mod04



Note that:

* all times are UTC time, not local time

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Analysis Tools  
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A number of tools for working with MODIS HDF data are available for download from this web site. These tools fall into three major categories, which are listed below. Under each main category, more detail on the function of each tool is offered.

1. Granule Locator Tools
   1. Locating Level-2 Granules from a Generic Global Map
   2. Locating Level-2 Granules from a Level-3 Global Image
   3. Locating Level-1B Granules using Text Input
   4. Locating Level-1B Granules using Level-1B Metadata
   5. Locating Level-2 Granules using Text Input
2. Spatial and Dataset Subsetting
   1. Subsetting Single Resolution HDF Files
   2. Subsetting Double Resolution HDF Files
3. Visualization & Analysis
   1. Visualizing HDF Data
   2. Extracting and Visualizing Bit Flags from Byte Data
   3. Creating the Atm. Standard Color Scale & Bar
   4. Creating Browse Images from Level-3 HDF Data
   5. Analyzing HDF Data

To learn more about and acquire these tools, visit the MODIS-Atmosphere:

<http://modis-atmos.gsfc.nasa.gov/tools.html>

**Important Tables**

TABLE 1: CHARACTERISTICS OF MODIS CHANNELS USED IN THE AEROSOL RETRIEVAL

|  |  |  |  |
| --- | --- | --- | --- |
| **Band Number** | **Bandwidth (μm)** | **Weighted Central Wavelength (μm)** | **Resolution (m)** |
| 1 | 0.620 - 0.670 | 0.646 | 250 |
| 2 | 0.841 - 0.876 | 0.855 | 250 |
| 3 | 0.459 - 0.479 | 0.466 | 500 |
| 4 | 0.545 - 0.565 | 0.553 | 500 |
| 5 | 1.230 – 1.250 | 1.243 | 500 |
| 6 | 1.628 – 1.652 | 1.632 | 500 |
| 7 | 2.105 – 2.155 | 2.119 | 500 |

TABLE 2: CONTENTS OF MODIS C005 AEROSOL LEVEL 2 FILE (MOD04/MYD04): OCEAN PRODUCTS

|  |  |  |
| --- | --- | --- |
| **Name of Product (SDS)** | **Dimesions: 3rd Dimension** | **Type of product** |
| Effective\_Optical\_Depth\_Average\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Retrieved Primary |
| Effective\_Optical\_Depth\_Best\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Retrieved Primary |
| Optical\_Depth\_Ratio\_Small\_Ocean\_0\_55micron | X,Y,2: average, best | Retrieved Primary |
| Solution\_Index\_Ocean\_Small | X,Y,2: average, best | Retrieved Primary |
| Solution\_Index\_Ocean\_Large | X,Y,2: average, best | Retrieved Primary |
| Least\_Squares\_Error\_Ocean | X,Y,2: average, best | Retrieved Diagnostic |
| Effective\_Radius\_Ocean | X,Y,2: average, best | Derived |
| Optical\_Depth\_Small\_Best\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Optical\_Depth\_Small\_Average\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Optical\_Depth\_Large\_Best\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Optical\_Depth\_Large\_Average\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Mass\_Concentration\_Ocean | X,Y,2: average, best | Derived |
| Cloud\_Condensation\_Nuclei\_Ocean | X,Y,2: average, best | Derived |
| Asymmetry\_Factor\_Best\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Asymmetry\_Factor\_Average\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Backscattering\_Ratio\_Best\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Backscattering\_Ratio\_Average\_Ocean | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Derived |
| Angstrom\_Exponent\_1\_Ocean(0.55/0.86 micron) | X,Y,2: average, best | Derived |
| Angstrom\_Exponent\_2\_Ocean(0.86/2.1 micron) | X,Y,2: average, best | Derived |
| Cloud\_Condensation\_Nuclei\_Ocean | X,Y,2: average, best | Derived |
| Optical\_Depth\_by\_models\_ocean | X,Y,9: 9 models | Derived |
| Cloud\_Fraction\_Ocean | X,Y: | Diagnostic |
| Number\_Pixels\_Used\_Ocean | X,Y: | Diagnostic |
| Mean\_Reflectance\_Ocean | X,Y: | Diagnostic |
| STD\_Reflectance\_Ocean | X,Y: | Diagnostic |
| Aerosol\_Cldmask\_Byproducts\_Ocean | X,Y: | Diagnostic |
| Quality\_Assurance\_Ocean | X,Y,5 bytes | Diagnostic |
| Optical\_Depth\_Land\_And\_Ocean | X,Y: 0.55μm | Joint (QAC≥0) \*\* |
| Image\_Optical\_Depth\_Land\_And\_Ocean | X,Y: 0.55μm | Joint (QAC≥0) |
| Optical\_Depth\_Ratio\_Small\_Land\_And\_Ocean | X,Y: 0.55μm | Joint (QAC≥0) |

X = 135; Y = 203. If there is a 3rd dimension of the SDS, then the indices of it are given. The “Retrieved” parameters are the solution to the inversion,whereas “Derived” parameters follow from the choice of solution. “Diagnostic” parameters aid in understanding of the directly Retrieved or Derived products. “Experimental” products are unrelated to the inversion but may have future applications. “Joint” products are the combined land and ocean products, with associated QAC constraint (for over ocean) in parentheses. \*\*Based on evaluation of operational C005-O data, the QAC for quantitative studies should be limited to QAC≥1 only.

Some of the ocean products are combined with products from land (discussed in the next section) as the *Joint* products. For AOD, two joint products are reported, the ‘Optical\_Depth\_Land\_And\_Ocean’ and the ‘Image\_Optical\_Depth\_Land\_And\_Ocean’. The first product is supposed to have more quantitative meaning, so is constrained by QAC. In practice, however, the two joint products are identical over ocean, meaning that the values of ‘Effective\_Optical\_Depth\_Average\_Ocean’ (at 0.55μm) are written into both SDSs, regardless of QAC. The ‘Optical\_Depth\_Ratio\_Small\_Ocean’ product is copied (regardless of QAC) into ‘Optical\_Depth\_Ratio\_Small\_Land\_And\_Ocean’. Quality Assurance confidence (QAC) value ranges from 0 (bad quality) to 3 (good quality).

A *Retrieved* parameter is one that is a solution to the AOD retrieval procedure. *Derived* parameters are computed based on products directly retrieved. For example, the Ångstrom Exponent is derived based on the spectral AOD that characterizes the retrieved solution. Products that are *Diagnostic* include QA parameters and those parameters that were calculated during intermediate steps. These diagnostic parameters can be used to understand how the retrieval worked. Products denoted *Experimental* are superfluous to the main retrieval procedure, but are useful in other applications.

Aerosol models are: Continental, Moderately Absorbing/Developing World, Non-absorbing/Urban-Industrial, Absorbing/Smoke, Spheroid and Dust.

TABLE 3: CONTENTS OF MODIS C005 AEROSOL LEVEL 2 FILE (MOD04/MYD04): LAND PRODUCTS

|  |  |  |
| --- | --- | --- |
| **Name of Product (SDS)** | **Dimesions: 3rd Dimension** | **Type of product** |
| Corrected\_Optical\_Depth\_Land | X,Y,3: 0.47, 0.55, 0.66 μm | Retrieved Primary |
| Corrected\_Optical\_Depth\_Land\_wav2p1 | X,Y,1: 2.12 μm | Retrieved Primary |
| Optical\_Depth\_Ratio\_Small\_Land | X,Y: (for 0.55 μm) | Retrieved Primary |
| Surface\_Reflectance\_Land | X,Y,3: 0.47, 0.66, 2.12 μm | Retrieved Primary |
| Fitting\_Error\_Land | X,Y: (at 0.66 μm) | Retrieved By-Product |
| Quality\_Assurance\_Land | X,Y,5: 5 bytes | Diagnostic |
| Aerosol\_Type\_Land | X,Y: | Diagnostic |
| Angstrom\_Exponent\_Land | X,Y: (for 0.66/0.47 μm) | Derived |
| Mass\_Concentration\_Land | X,Y: | Derived |
| Optical\_Depth\_Small\_Land | X,Y,4: 0.47,0.55,0.66,2.12 μm | Derived |
| Mean\_Reflectance\_Land | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Diagnostic |
| STD\_Reflectance\_Land | X,Y,7: 0.47,0.55,0.66,0.86,1.2,1.6,2.12μm | Diagnostic |
| Cloud\_Fraction\_Land | X,Y: | Diagnostic |
| Number\_Pixels\_Used\_Land | X,Y: | Diagnostic |
| Path\_Radiance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Error\_Path\_Radiance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Critical\_Reflectance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Error\_Critical\_Reflectance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Quality\_Weight\_Path\_Radiance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Quality\_Weight\_Crit\_Reflectance\_Land | X,Y,2: 0.47, 0.66 μm | Experimental |
| Optical\_Depth\_Land\_And\_Ocean | X,Y: (for 0.55 μm) | Joint (QAC≥0) \*\* |
| Image\_Optical\_Depth\_Land\_And\_Ocean | X,Y: (for 0.55 μm) | Joint (QAC≥0) |
| Optical\_Depth\_Ratio\_Small\_Land\_And\_Ocean | X,Y: (for 0.55 μm) | Joint (QAC≥0) |
| *From MYD04\_L2(MODIS AQUA)* | | |
| Deep\_Blue\_Aerosol\_Optical\_Depth\_550\_Land | X,Y:(for 0.55 μm) | Derived |
| Deep\_Blue\_Aerosol\_Optical\_Depth\_Land | X,Y,3: 0.412, 0.47, and 0.66μm | Derived |
| Deep\_Blue\_Angstrom\_Exponent\_Land | X,Y:(0.412-0.47) μm | Derived |
| Deep\_Blue\_Single\_Scattering\_Albedo\_Land | X,Y,3: 0.412, 0.47, and 0.66μm | Derived |
| Deep\_Blue\_Surface\_Reflectance\_Land | X,Y,3: 0.412, 0.47, and 0.66μm | Derived |

How to read MODIS AOD in Matlab:

1-To read from the hdf file:

When reading one file:

fname='filename.hdf';

hdfread(fname,'Parameter\_name');

When reading several files

fid=fopen('filename\_list.txt','r');

for loop with the size of filename\_list

fname=fscanf(fid,'%s',1);

hdfread(fname,'Parameter\_name');

2-Parameters from the hdf file that should be read:

TABLE 4: Used SDS from MOD04/MYD04

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Dimensions** | **Fill Value** | **Scale Factor** |
| Longitude | 203x135 | -999 | 1 |
| Latitude | 203x135 | -999 | 1 |
| Aerosol\_Type\_Land | 203x135 | -9999 | 1 |
| Sensor\_Zenith | 203x135 | -9999 | 0.01 |
| Sensor\_Azimuth | 203x135 | -9999 | 0.01 |
| Solar\_Zenith | 203x135 | -9999 | 0.01 |
| Solar\_Azimuth | 203x135 | -9999 | 0.01 |
| Scattering\_Angle | 203x135 | -9999 | 0.01 |
| Corrected\_Optical\_Depth\_Land | 3x203x135 | -9999 | 0.001 |
| Mean\_Reflectance\_Land | 7x203x135 | -9999 | 0.0001 |
| Surface\_Reflectance\_Land | 3x203x135 | -9999 | 0.001 |
| Optical\_Depth\_Small\_Land | 4x203x135 | -9999 | 0.001 |
| Critical\_Reflectance\_Land | 2x203x135 | -9999 | 0.0001 |
| Path\_Radiance\_Land | 2x203x135 | -9999 | 0.0001 |
| Angstrom\_Exponent\_Land | 203x135 | -9999 | 0.001 |
| Corrected\_Optical\_Depth\_Land\_wav2p1 | 203x135 | -9999 | 0.001 |
| Quality\_Assurance\_Land | 203x135x5 bytes | none | 1 |
| Cloud\_Mask\_QA | 203x135x5 | none | 1 |

Description of the QA flags:

TABLE 5: Cloud\_mask\_QA flags

|  |  |  |  |
| --- | --- | --- | --- |
| QA Flag Name | Number of Bits | Bit Value | Description |
| Cloud Mask | 1 | 0  1 | Undetermined  Determined |
| Cloud Mask Quality Flag | 2 | 0  1  2  3 | 0-25% Cloudy pixels  25-50% cloudy pixels  50-75% cloudy pixels  75-100%cloudy pixels |
| Day/Night flag | 1 | 0  1 | Night  Day |
| Sun glint flag | 1 | 0  1 | Yes  No |
| Snow/Ice flag | 1 | 0  1 | Yes  No |
| Land/Water flag | 2 | 0  1  2  3 | Water (ocean)  Coastal  Desert  Land |

TABLE 6: QUALITY ASSURANCE LAND FLAGS (5 bytes = 40 bits)

|  |  |  |  |
| --- | --- | --- | --- |
| **Flag Name** | **Number of Bits** | **Bit Value** | **Description** |
| 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  So 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  *Note: Flags 2 and 3 are reversed from the Aerosol Type (over land only) above* | 2 | 0  1  2  3 | Mixed  Dust  Smoke  Sulfate |
| 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 |

Notes on the QA flags:

Please remember that when you read these flags, they’re in uint8 type. So what you need to do is the following:

You’re gonna change the value to binary. Use the function dec2bin in Matlab to do the conversion. Remember that you have to indicate whether you want to convert the number to 8 bits or 16 bits, etc.

For example:

*Variable\_binary=dec2bin(variable\_decimal,16);*

In the case of Cloud\_Mask\_QA, you have 8 bits.

cmqa=reshape(dec2bin(double(Cloud\_Mask\_QA),8),203,135,8);

cmqa is a variable of size 203x135x8 and if I want to see what is bit 0 I access (:,:,1) for example.

Also remember that bits are represented in Little-Endian.



In the case of Quality\_Assurance\_Land, you have 40 bits but they’re distributed in the following way:

The first 8 bits as indicated in the table by yellow correspond to (:,:,1)

Next 8 bits as indicated in the table by orange correspond to (:,:,2)

Again the ones indicated by green correspond to (:,:,3)

The ones indicated by blue correspond to (:,:,4) and finally the ones indicated by lavender correspond to (:,:,5).

Qal1=reshape(dec2bin(double(Quality\_Assurance\_Land(:,:,1)),8),203,135,8);

3-For every file we need to calculate the minimum distance to find the closest pixel to the AERONET site.

First, we define latitude and longitude coordinates for the AERONET Site (the AERONET header provides that information). Since we have the variables Longitude and Latitude from the hdf file, we can calculate the minimum distance in the following way:

x1=longitude\_AERONET

x=double(longitude\_hdf)

y1=latitude\_AERONET

y=double(latitude\_hdf)

[R,C]= min[((x-x1)2+(y-y1)2)1/2]

[K,L]=min(R);

row\_index=C(L);

column\_index=L;

4-After the row and column indexes are calculated, do the following:

Assign a temporary variable for each parameter and take into account the following cases:

-Check if the [row index >203 or <1] or [column index >135 or <1], if this is the case then each temporary variable should be set to NaN.

-For fill values, if any of the parameters at (row\_index,column\_index)= -9999, set them to NaN.

-Else, temporary\_variable=double(parameter(row\_index,column\_index))\*scale\_factor

5-For each parameter, create a variable that will get the temporary assigned value for each file.

For example:

AOD(1:3,file)=AODtemp;

MeanReflectance(1:7,file)=MeanReflectancetemp;

SensorZenith(file)=SensorZenithtemp;