Update March 2023: VIIRS v2.0 for SNPP and NOAA-20

Dark Target VIIRS version 2.0 includes VIIRS NOAA-20 (AERDT_L2_VIIRS_NOAA20) for the first time, and also makes several changes to the algorithm compared to VIIRS version 1.1.

SNPP v1.1 vs. v2.0

The largest algorithm changes are a higher-resolution cloud mask, which now uses the 375m "Image" red-wavelength bands to allow for closer near-cloud retrievals with less cloud contamination, and a move from NOAA's Global Data Assimilation System (GDAS) to NASA's Global Modeling and Assimilation Office (GMAO) as the source of ancillary meteorological data (surface wind, column ozone, and precipitable water vapor). Version 2.0 also makes use of updated VIIRS L1b reflectances (VIIRS L1 Processing Group), which have improved calibration compared to the previous version. The Dark Target product now reports the mean and standard deviation reflectances over land for all seven wavelength bands, as previous versions did only over ocean. There are also several small bug fixes and corrections to the metadata.

The improved cloud mask is especially visible over ocean, where many high AOD values are revised downward.

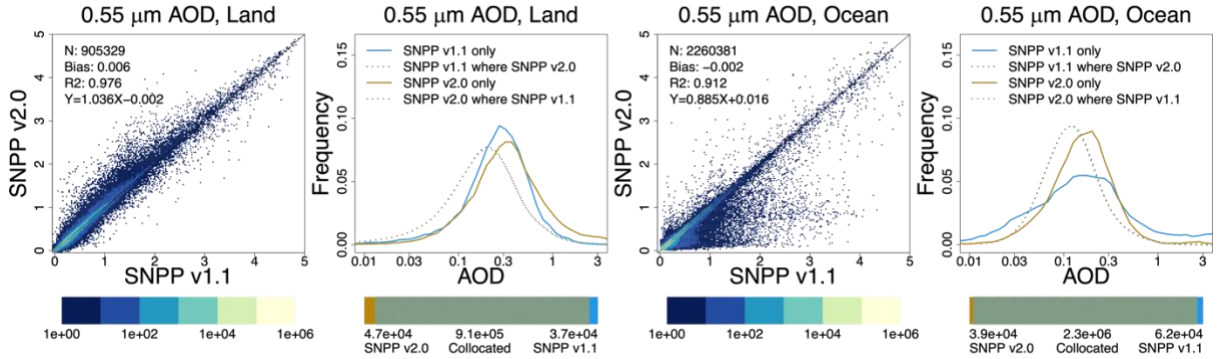


Figure 1. Comparison between daily gridded average (1°×1°) QA-filtered AOD at 0.55 μm over land (left) and ocean (right) for AERDT_L2_VIIRS_SNPP v1.1 vs. v2.0, May-August 2019.

VIIRS v2.0 tends to have higher AOD values over land. As with most comparisons between different sensors, the AOD distributions differ the most in grid boxes where one version was able to retrieve and the other was not. Unlike the daily gridded average values, the monthly average values represent many orbital passes that are not necessarily matched to one another for comparison.

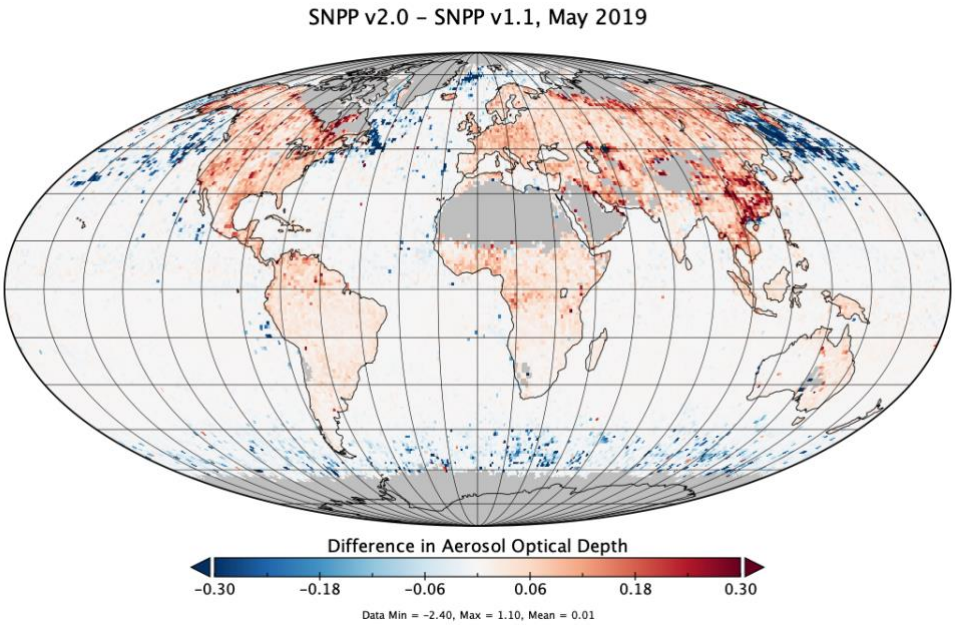


Figure 2. Difference in monthly gridded average QA-filtered AOD between v1.1 and v2.0 for May 2019.

SNPP v2.0 vs. NOAA-20

The SNPP and NOAA-20 spacecraft both operate in ascending polar orbits with an equatorial crossing time of 1:30 PM local time, but with half an orbit's separation between them (see video from NASA Scientific Visualization Studio here). Their field of view never overlaps, although the exact time between SNPP and NOAA-20 observations of the same spot varies.

VIIRS NOAA-20 and NOAA-21 have slightly different spectral response functions from VIIRS SNPP. For SNPP, the wavelengths used for retrieval are 0.49, 0.55, 0.67, 0.86, 1.24, 1.60, and 2.26 μm. For NOAA-20, they are 0.49, 0.56, 0.67, 0.87, 1.24, 1.60, and 2.26 μm. Wavelength channels are described accordingly in the file metadata. Note that while NOAA-20 lists a 0.56 μm green channel for reflectances, the aerosol values for the green channels on both SNPP and NOAA-20 are retrieved at a MODIS-like 554 nm.

NOAA-20 also has its own calibration, and AOD values retrieved by the same algorithm show an offset between SNPP and NOAA-20. Reflectances are generally a few percentage points lower for NOAA-20 than for SNPP, and retrieved aerosol values follow suit. This likely reflects a high bias in SNPP rather than a low bias in NOAA-20, but more detailed validation will soon be available elsewhere on the Dark Target website.

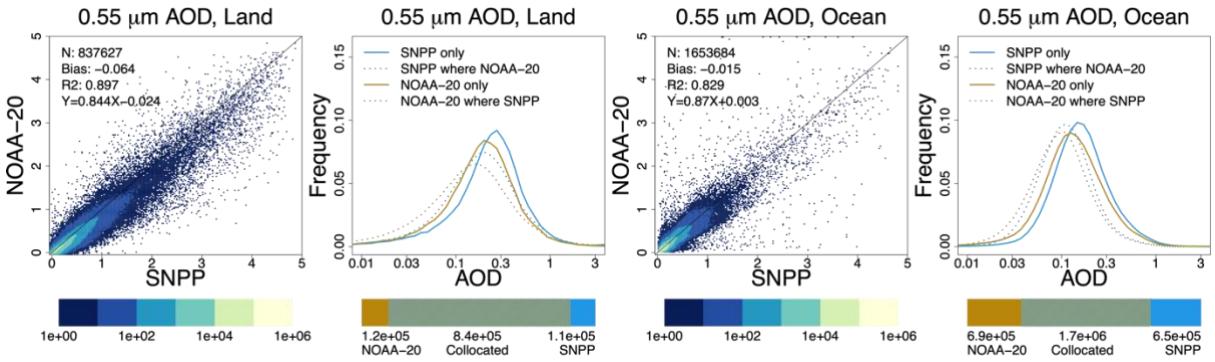


Fig. 3. Comparison between daily gridded average (1°×1°) QA-filtered AOD at 0.55 μm over land (left) and ocean (right) for AERDT_L2_VIIRS_SNPP v2.0 vs. AERDT_L2_VIIRS_NOAA20, May-August 2019.

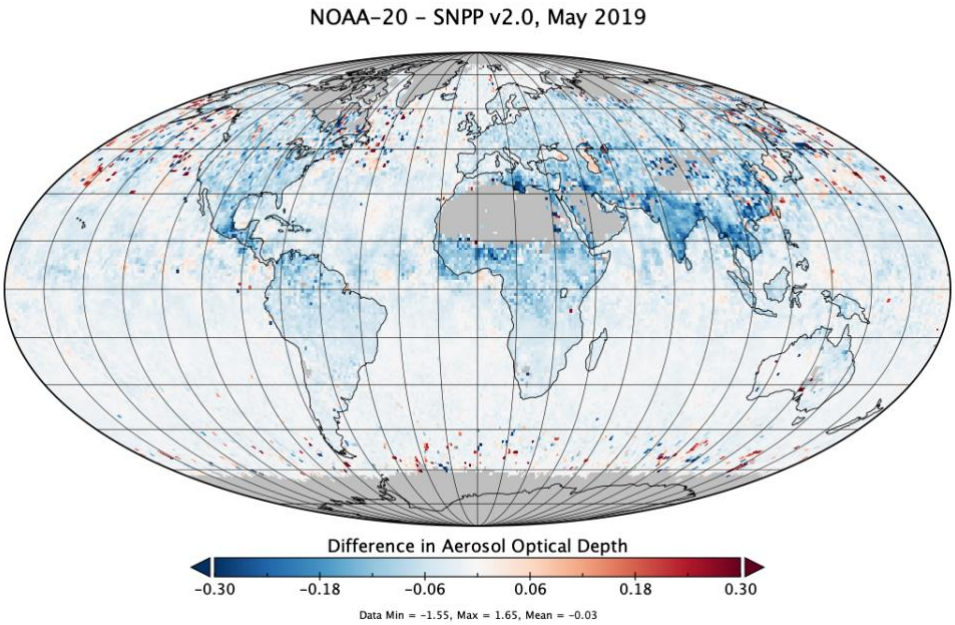


Fig. 4. Difference in monthly gridded average QA-filtered AOD between SNPP and NOAA-20 for May 2019.

1. Introduction

There are several NASA satellite remote sensing aerosol products available for research and public use. This users guide will focus on aerosol products created using the Dark Target (**DT**) algorithm(s). Much of the information in this guide can also be found on-line in the "Products" section of the DT website.

The **DT** products have been in use since the launch of the polar orbiting Terra MODIS sensor in 1999 and on Aqua MODIS since 2002. DT products have been adapted to the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor. Three VIIRS instruments are currently in orbit, aboard Suomi-NPP, NOAA20, and NOAA21, and future launches are planned. DT products are also in the process of being ported to the Advanced Baseline Imager (ABI) on the geosynchronous orbiting GOES-R satellite series as well as the Advanced Himawari Imager (AHI) on the Himawari satellite platform.

Owing to the long association of the DT products with the MODIS sensor this guide has been written with a focus on the MODIS DT. There are many similarities between the MODIS and VIIRS products so much of the information in the guide is also applicable to VIIRS. When differences occur each section of the guide will also include specific instructions for VIIRS.

This guide will focus on the DT products and their proper usage but will not go into detail on the DT algorithm. A comprehensive description of the MODIS DT algorithm, the Algorithm Theoretical Basis Document (ATBD), is available in the ATBD section of NASA's Dark Target website https://darktarget.gsfc.nasa.gov/. As with this guide sections pertaining to the algorithm adjustments for VIIRS can also be found on the dark target website.

All satellite remote sensing aerosol products must contend with the problem of separating the aerosol signal from the surface signal observed by the sensor. The **DT** algorithm relies on the phenomena that aerosols over a dark surface target will generally brighten the observed scene in order to separate these signals. Where the surface is bright, such as over ocean glint or desert areas, the **DT** algorithm will not create a product retrieval. NASA also provides MODIS and VIIRS Deep Blue (**DB**) products which are more successful in providing aerosol information over bright surfaces. There is a combined MODIS DT-DB land product which attempts to merge the best retrievals from both products. The merged product will also be discussed in this guide. DB will only be discussed in this guide in terms of its availability in the merged product. For more information on MODIS or VIIRS DB please visit their website.

There is also a higher resolution MODIS aerosol product the Multi-Angle Implementation of Atmospheric Correction product (MAIAC). MAIAC will not be covered in this guide. For more information look here.

2. MODIS and VIIRS Instruments

Although quite similar in their design and capabilities there are significant differences between the two sensors that can and do result in differences in their products.

Instrument	MODIS (Aqua)	VIIRS (SNPP)
Orbit Altitude	705 Km	824 Km
Equatorial Crossing Time	13:30 Local Time	13:30 Local Time
Measurement Swath Width	2330 Km	3040 Km
Nadir Pixel Size (primary retrieval band)	0.5 Km, 1.0 Km	0.375, 0.75 Km
Swath Edge Pixel Size	2 Km	1.5 Km
Spectral Bands Used for Retrieval	0.47, 0.55, 0.65, 0.86, 1.24, 1.38, 1.63, and 2.11 μm	0.49, 0.55, 0.67, 0.86, 1.24, 1.38, 1.61, and 2.25 μm

Table 1. MODIS and VIIRS instrument design parameters.

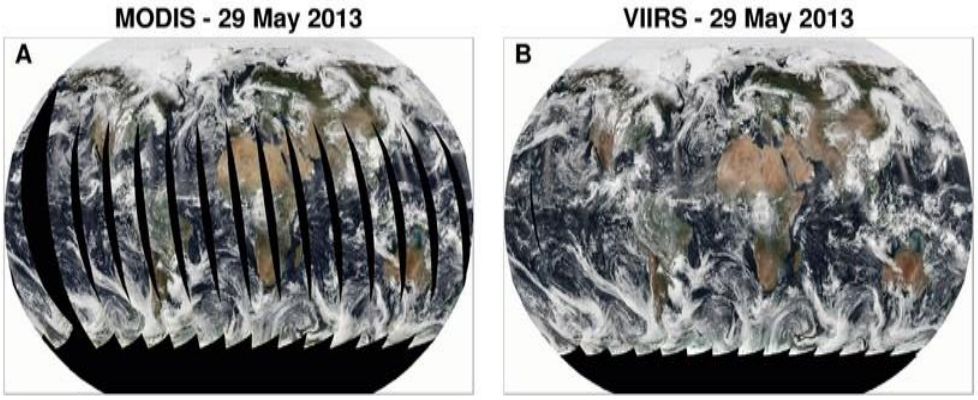


Figure 1. The true color images above taken from each sensor show one full day of data coverage. MODIS has gaps in its coverage near the equator. VIIRS' wider swath width eliminates these gaps.

The table below summarizes some of the product differences between MODIS and VIIRS some of which are consequences of the different sensor capabilities and orbit. Other differences have to do with product creation choices and/or algorithm changes. These will be explained in more detail in the rest of the guide.

Sensor	MODIS	VIIRS
Nadir Product Size	10 x 10 Km	6 x 6 Km
Number of pixels aggregated for product	100 1 Km pixels	64 0.75 Km pixels
Granule Size	5 Minutes; 203 x 135 pixels	6 Minutes; 404 x 400 pixels
File format	HDF4	netCDF-4

Table 2: MODIS and VIIRS Level 2 aerosol product comparison.

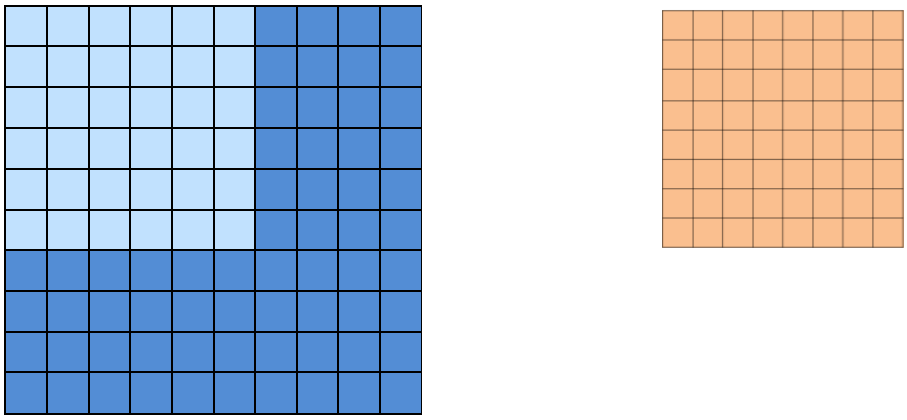


Figure 2. Product Sizes: At left: MODIS 10×10 km level 2 pixel retrieved from 1×1 km level 1b pixels, compared to the size of the VIIRS level 2 product size in lighter blue. At right: VIIRS 6×6km product retrieved from 0.75×0.75 km level 1b pixels.

DT Aerosol Products Overview

Aerosol & Atmosphere Products

Aerosol products are a subset of a larger group of atmosphere products. In addition to the aerosol products there are separate atmosphere products such as cloud and water vapor products. The product file names

provide information about the product type, content and resolution. The naming conventions for the aerosol products are described below.

Atmosphere products, including the aerosol products, are archived and can be obtained at the LAADS DAAC and also at the EARTHDATA portal. Either site can be used to search for and download data. Note that the two sites are not identical and have different search and visualization capabilities. MODIS product files are stored in HDF format. ***VIIRS product files are in NETCDF format***. A downloadable tutorial for LAADS DAAC site and several other remote sensing resources is available on the NASA ARSET website. Another easy way to visually search and find files for an individual event is to use the NASA Worldview site. Worldview has an online tutorial.

In addition to the information available in this guide the MODIS-atmos product pages provide an excellent overview as well as in-depth information on not only the MODIS aerosol product but also the water vapor, cloud, cloud mask and aerosol profile products. New and intermediate users of MODIS atmosphere data would do well to familiarize themselves with this content available there as well as bookmark it for reference. MODIS-atmos has recently added a section on "continuity products". These are products developed initially for MODIS but updated around a common core to allow porting to VIIRS and other instruments. The DT VIIRS product is one of the continuity products.

Product Collections

NASA satellite product developers are constantly working to evaluate, update and improve their products. From time to time after significant changes are made to the algorithm and/or instrument calibration the entire data set for a single or related group of instrument products will be reprocessed using the new algorithm and/or calibration. The set of data products created using the same set of algorithms and calibration coefficients is referred to as a collection. MODIS Collection 6 (C6) was released in 2016 for all atmosphere products. A smaller update was later applied and, as of this writing the current MODIS collection is Collection 6.1 (C6.1). Generally, only the most recent data set is available to the public for use. If older data collections are required one should inquire with the NASA LAADS DAAC.
VIIRS products are collection 2.0 (designated in the file names as 002). When searching for VIIRS level 2 data at LAADS DAAC, after selecting the VIIRS:Suomi-NPP product, users will need to select VIIRS Collection 2 – Level 1, Atmosphere, Land (Archive Set 5200). The previous operational version, VIIRS Dark Target for SNPP version 1.1, is available under Archive Set 5110.

Level 2 Aerosol Products Overview

Satellite geophysical products (as opposed to raw data) from polar orbiting instrument are created from individual overpasses of the satellite sensor and are designated as Level 2 products. The Level 2 products are made available in files which are short segments from the full orbit and are referred to as granules. MODIS granules correspond to 5 minute segments and **VIIRS granules are 6 minute segments**. Geolocation information is contained within the product files so there are no separate data and metadata files as are found in some satellite products. The Terra, Aqua and SUOMI-NPP satellites have a 16 day orbital cycle. Granules from an individual sensor with the same time designation which are 16 days apart should be observing the same geographic location with the same geometry unless an orbital maneuver has been performed in the intervening time period.

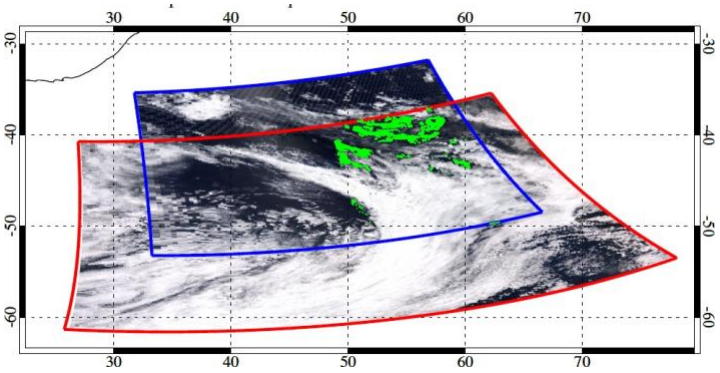


Figure 3. Example of a MODIS 5 minute (blue outline) vs VIIRS 6 (red outline) minute granule coverage. Figure is taken from Sayer et. al. 2015.

MODIS and VIIRS Level 2 Aerosol Products Summary and File Naming

Product Name	Sensor	Product Resolution	Product Level	Size/Time	File Dimensions
MOD04_L2	MODIS-Terra	10 Km	2	Granule/5 minute	204 x 135
MYD04_L2	MODIS-Aqua	10 Km	2	Granule/5 minute	204 x 135
MOD04_3K	MODIS-Terra	3 Km	2	Granule/5 minute	676 x 451
MYD04_3K	MODIS-Aqua	3 Km	2	Granule/5 minute	676 x 451
AERDT_L2_VIIRS_SNPP	**VIIRS- SNPP**	**6 Km**	**2**	**Granule/6 minute**	**404 x 400**
AERDT_L2_VIIRS_NOAA20	**VIIRS – NOAA20**	**6 Km**	**2**	**Granule/6 minute**	**404 x 400**

Table 3.

The designation as a 10 km, 6 km or 3 km aerosol product refers to the resolution of the product (not the sensor!) **at the center of the satellite swath**. These products include retrieval parameters over land and ocean.

MODIS 10 km Aerosol HDF file names have the following naming convention:
Terra file: MOD04_L2.AYYYYDDD.HHMM.CCC.YEARDAYHRMNSC.hdf
Aqua file: MYD04_L2.AYYYYDDD.HHMM.CCC.YEARDAYHRMNSC.hdf

YYYY, DDD and HHMM are the four digit year, three digit Julian day, and time of day (hours and minutes) in UTC, CCC is the collection (006 for C6, 061 for C6.1), and YEARDAYHRMNSC represents when the file was processed. 3 Km products will follow the same rules but will start with MOD04_3K or MYD04_3K.

Each retrieval parameter within a product file is termed a Scientific Data Set (**SDS**). The MODIS 10 km product will include some SDS parameters from the Deep Blue algorithm as well as from the merged dark target-deep blue product. SDS names will indicate if the parameter contains ocean data, land data, or combined ocean and land data. All SDSs are DT unless the name explicitly indicates Deep Blue or a merged product. The 3 km product contains only dark target (no deep blue or merged) SDSs over both land and ocean. **VIIRS products do not have a Deep Blue component.**

VIIRS files use the following naming conventions which are very similar to MODIS:

AERDT_L2_VIIRS_SNPP.AYYYYDDD.HHMM.VVV.YEARDAYHRMNSC.nc

YYYY, DDD and HHMM are the four digit year, three digit Julian day, and time of day (hours and minutes) in UTC, CCC is the collection and YEARDAYHRMNSC represents when the file was processed.

Product File Dimensions

Product file dimensions are a function of the granule size, swath width, pixel size and viewing geometry. **MODIS 10 Km:** The dimensions of the level 2 10 km granule files are 204 (along swath) x 135 (across swath). This represents the number of 10 km pixels in the granule file array. Along swath refers to the path of the satellite and across swath is perpendicular to this direction. In actuality the product is 10 km x 10 km near nadir but the pixels expand in the across swath direction. The further from nadir the greater the expansion due to the "bow tie" effect. This is an effect of the viewing geometry where the pixels grow in size as they approach the end of the swath. At the end of the swath the product may be closer to 40 x 40 km.

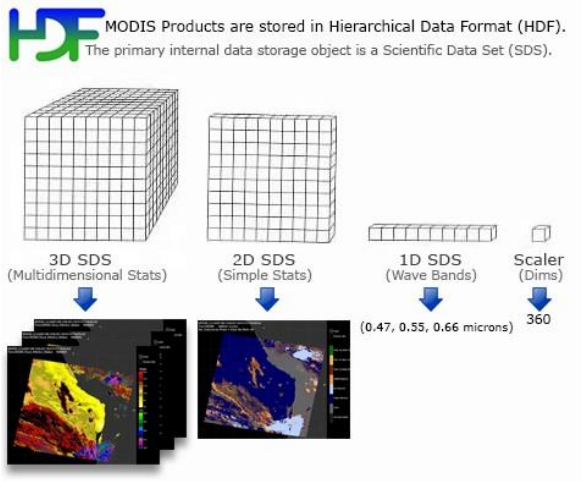
MODIS 3 KM: Product granule file dimensions of the level 2 3 km files are 676 (along swath) x 451 (across swath)

VIIRS: The dimensions of the VIIRS 8 km files are 400 (along swath) x 400 (across swath). The effects of the "bow tie" effect have been reduced in VIIRS due to both sensor design and data handling choices. Product dimension at the edge of the swath are approximately 16 x 16 km.

3. DT Level 2 Aerosol Products In-Detail

Aerosol Product File Format Basics

HDF formatting as used in MODIS is illustrated below. The VIIRS dimensional organization is identical however the file is stored in netCDF-4 format.



All modern computer languages used for analysis will have the capability to read both HDF and netCDF files, if not natively then with a dedicated package.

The VIIRS Dark Target files are saved in netCDF4 format, which is intercompatible with HDF5 (MODIS uses HDF4). Programming functions intended to read HDF5 files will generally work with the VIIRS files, but functions intended for netCDF3 may have unpredictable results, and HDF4 functions will not recognize the file. The most important new feature of the format is the ability to organize datasets into groups, in this case geolocationdata for coordinates and angle information, and geophysical data for datasets from the Dark Target retrieval. In some programming languages, a dataset within a group can be accessed by combining the group and dataset name, for example in IDL:

datasetID = h5d_open(fileID,'/geophysical_data/Optical_Depth_Land_And_Ocean')

Other languages require a command to look up the group ID first, which can then be used in place of the file ID to look up the dataset. See table 4 below for more information.

Official netCDF information, including sample code in several languages:
https://www.unidata.ucar.edu/software/netcdf/

Level 2 Product Contents

All DT product have separate and distinct retrieval algorithms for data collected over land or over ocean however values derived from both algorithms are reported out in each level 2 file. For a general overview of the algorithm please look through the appropriate pages of the Aerosol Overview section of our website. For algorithm details please see our ATBD section of the website.

SDS Naming Conventions

SDS names will indicate if the parameter is coming from an ocean or land retrieval or if data from both are combined into a single SDS.

The example below illustrates the naming conventions for the SDS parameters in a 10 Km MODIS Terra Level 2 file. The overall parameter description comes first followed by the "Land", "Ocean", "Land_Ocean", "Deep Blue" or "Deep_Blue_Combined" designation. "Deep_Blue_Combined" refers to the merged DT_DB product. DB parameters are only available over land and only in the 10 KM product since DB does not have a 3Km product. If unspecified all SDS refer to a DT only product.

- Aerosol_Cldmask_Land_Ocean
- Aerosol_Cloud_Fraction_Land
- Aerosol_Cloud_Fraction_Ocean
- Aerosol_Type_Land
- Angstrom_Exponent_1_Ocean
- Angstrom_Exponent_2_Ocean
- AOD_550_Dark_Target_Deep_Blue_Combined

When attempting to call these parameters for computational analysis names must be exact and include underscores.

SDS Contents

Shown below is an explanation of the information content provided within each MODIS SDS using the variable "Corrected_Optical_Depth_Land" as an example. Dimensions for this MODIS SDS are 203 x 135 x 3 see description below.

Variable "Corrected_Optical_Depth_Land"

In file "MYD04_L2.A2018100.1820.061.2018101162651.hdf"

Var full name: mod04/Data_Fields/Corrected_Optical_Depth_Land

```
short Corrected_Optical_Depth_Land(Solution_3_Land=3, Cell_Along_Swath=203, Cell_Across_Swath=135);
  :valid_range = -100S, 5000S; // short
  :_FillValue = -9999S; // short
  :long_name = "Retrieved  AOT at 0.47, 0.55,0.66   micron";
  :units = "None";
  :scale_factor = 0.0010000000474974513; // double
  :add_offset = 0.0; // double
  :Parameter_Type = "Output";
  :Cell_Along_Swath_Sampling = 1, 2021, 10; // int
  :Cell_Across_Swath_Sampling = 1, 1354, 10; // int
  :Geolocation_Pointer = "Internal geolocation arrays";
```

short – variable specification

Solution_3_Land=3 number of values for parameters with multiple value output at each pixel (the z dimension of the sds)

Cell_Along_Swath and **Cell_Across_Swath** - the dimension of this parameter as returned by the algorithm in the x and y directions. In this case 203 and 135.

valid_range – the minimum and maximum raw values returned by the algorithm

_FillValue – the value returned when there is no algorithm retrieval

long_name – a brief text descriptor of the variable. When multiple wavelengths are mentioned in the long name there will be a third dimension for this SDS parameter. In this case 3, one for each wavelength.

units – unit descriptor or name applied to this variable

scale_factor – the scaling value applied to the raw numbers returned by the algorithm

add_offset – the offset value added to the raw numbers returned by the algorithm

Parameter_Type – Input or Output

Cell_Along_Swath_Sampling and **Cell_Across_Swath_Sampling**– interval number of rows or columns sampled, full number of values sampled in this dimension, number of values averaged to obtain output parameter. This refers to sampling from the level 1B raw calibrated data file.

You can use this link to the file spec page of the MODIS-Atmos site which gives a complete list of these outputs for all of the MOD04 MYD04 SDS parameters. Use this link for the 3 Km products

Aerosol Product SDS's Explained

The most important and frequently used parameters from the aerosol products relate to **aerosol optical depth (AOD),** and indicators of particle size such as **fine mode fraction, and angstrom exponent.** The background information for each grouping is the same for MODIS and VIIRS. We begin with a detailed explanation of the MODIS parameters and will then provide the equivalent information for VIIRS.

Aerosol Optical Depth (AOD)

The aerosol optical depth (AOD or τ; also called aerosol optical thickness or AOT) refers to the optical loading of the aerosols in the atmospheric column. AOD is a unitless value. It is most closely related to the total surface area of the aerosol. AOD is spectrally dependent, meaning it varies by wavelength. In general most remote sensing studies looking at AOD are using values at 0.55 microns.

Ground data from the **AE**rosol **RO**botic **NET**work (AERONET) is used to validate MODIS , VIIRS and many other aerosol products. A full discussion of AERONET is beyond the scope of this guide but users should be aware that AERONET measurements are made at 0.50 microns and interpolated to 0.55 when compared to MODIS or VIIRS.

The most commonly used SDS's pertaining to AOD are listed here and explained below:

Corrected_Optical_Depth_Land

Effective_Optical_Depth_Average_Ocean

Optical_Depth_Land_And_Ocean

Image_Optical_Depth_Land_And_Ocean

Land_Ocean_Quality_Flag

Deep_Blue_Aerosol_Optical_Depth_550_Land

Deep_Blue_Aerosol_Optical_Depth_550_Land_Best_Estimate

Deep_Blue_Aerosol_Optical_Depth_550_Land_QA_Flag

AOD_550_Dark_Target_Deep_Blue_Combined

AOD_550_Dark_Target_Deep_Blue_Combined_Algorithm

AOD_550_Dark_Target_Deep_Blue_Combined_QA_Flag

The DT product for both MODIS and VIIRS includes small negative Aerosol Optical Depth retrieval values in order to avoid an arbitrary negative bias at the low AOD end in long term statistics. This is because neither instrument has enough sensitivity over land to retrieve aerosol to better than +/-0.05. The consequence is that in very clean conditions the algorithm cannot truly distinguish between AOD values in

the range of -0.05 to 0.05. If we eliminate all the negative numbers and keep only the positive numbers, we would introduce an artificial bias to the long term statistics, therefore we allow negative retrievals down to -0.05. For end users: If you are calculating long-term statistics simply include the negatives in your analysis. If you are looking at individual retrievals then count negative retrievals as 'very clean'. You could force them to be AOD = 0, for example. It really depends on the application. However, these small negative AOD values are valid retrievals and do contain useful information.

Retrieval Product Quality

All of the AOD products come with an indicator of the quality of the retrieval referred to as the QA flag, with a value at each (retrieval) pixel location. QA flag values are found in an SDS that is separate from the product value SDSs. QA flag values range from the lowest quality of 0 to the highest quality of 3. For Land based products we suggest using only QA 3. For Ocean based products we suggest using only QA 2 and 3. Note that several other remote sensing products come with a QA flag where 0 is considered the highest quality.

Corrected_Optical_Depth_Land – optical depth reported from the land retrieval at 0.47, 0.55, and 0.66 microns. Minimum Value is -0.05 and Maximum Value is 5.00.

MODIS has a separate SDS of Corrected_Optical_Depth_Land_wav2p1 for AOD at 2.1 microns

While negative values do not indicate an actual value occurring in nature they are allowed in our retrieval product to produce better overall aggregate retrieval statistics. Only QA value 3 is recommended for use. "Corrected" in the SDS name is a legacy from earlier products. There is no "Uncorrected" version of this SDS.

The VIIRS DT version reports the land retrieval in a single SDS at 0.48, 0.55, 0.67, and 2.2 microns.

Effective_Optical_Depth_Average_Ocean – optical depth reported from the ocean retrieval at 0.47, 0.55, 0.66, 0.86, 1.24, 1.63, and 2.13 microns. Minimum Value is -0.10 and Maximum Value is 5.00. While negative values do not indicate an actual value occurring in nature they are allowed in our retrieval product to produce better overall aggregate retrieval statistics. Only QA values of 2 and 3 are recommended for use. This SDS averages all retrievals within the algorithm's acceptable error limits. There is another ocean SDS, Effective_Optical_Depth_Best_Ocean, that returns the retrieval with the lowest fit error. The Average result SDS is preferred for use. **VIIRS does not include the Effective_Optical_Depth_Best_Ocean sds.**

Optical_Depth_Land_And_Ocean – optical depth retrievals for land and ocean reported only at 0.55 microns and only for high quality retrievals, QA 3 for Land QA 2-3 for Ocean. Minimum Value is -0.10 and Maximum Value is 5.00. This SDS is suggested for use when the user only wishes to look at our recommended quality data and only at 0.55 microns.

Image_Optical_Depth_Land_And_Ocean - optical depth retrievals for land and ocean reported for all qualities of data (0 – 3) at 0.55 microns. This SDS is suggested for use only to provide the greatest coverage when producing images and not for quantitative studies.

Land_Ocean_Quality_Flag – Quality assurance (QA) flags for the Ocean and Land aerosol retrieval. Range of values is 0 – 3 where zero is lowest quality. QA values are subjectively assigned by the algorithm team based on numerical standards such as number of input pixels used for the retrieval, proximity to bright land or ocean glint and error fitting values.

Deep_Blue_Aerosol_Optical_Depth_550_Land – optical depth retrievals using the DB algorithm at 0.55 microns for all quality of data. QA flags are 1,2 or 3 where 1 is low. AOD values range from 0 to 5.

Deep_Blue_Aerosol_Optical_Depth_550_Land_Best_Estimate - optical depth retrievals using the DB algorithm at 0.55 microns for higher quality data for DB (QA 2 or 3). AOD values range from 0 to 5.

Deep_Blue_Aerosol_Optical_Depth_550_Land_QA_Flag - Quality assurance (QA) flags for DB Land aerosol retrieval. Range of values is 1 – 3 where one is lowest quality

AOD_550_Dark_Target_Deep_Blue_Combined – AOD at 0.55 micron for land and ocean. DT values are used over ocean. Over land the algorithm will select the product, either DT or DB, with the higher QA value. When QA values are equal the DT-DB values are averaged.

AOD_550_Dark_Target_Deep_Blue_Combined_Algorithm_Flag – Flag indicating which algorithm was selected for the value of the land retrieval (0 – Dark Target, 1 – Deep Blue, 2 – Mixed).

AOD_550_Dark_Target_Deep_Blue_Combined_QA_Flag – Flag indicating the QA value of the AOD retrieval in the merged product. Range is 0 – 3 where zero is low.

Parameters Related to Particle Size

Fine and Coarse Mode

In general atmospheric aerosols occur in a bimodal distribution and the dark-target algorithm operates under this assumption. The smaller particles are referred to as the fine mode or accumulation mode aerosols. These particles have radii between 0.1 and 0.25 microns. The larger particles comprise the coarse mode. These particles generally have radii between 1.0 and 2.5 microns. The aerosol fine mode fraction is the proportion of fine mode aerosols to the total. This is an optical measurement of the proportion by volume. The proportion of aerosol attributed to fine or coarse mode can then be multiplied by the total AOD to determine the fine or coarse mode AOD. The proportional AOD is only reported for the ocean product. We feel that the algorithms' ability to distinguish fine or coarse mode over land is not accurate enough to permit us to make a fine mode AOD calculation. Note that there is no QA value for the following parameters.

Optical_Depth_Ratio_Small_Land- Fraction of AOD contributed by the fine dominated model for land at 0.55 microns. Valid Range: 0 to 1

Optical_Depth_Ratio_Small_Ocean - Ratio of Optical Depth of Small Mode vs Effective Optical Depth at 0.55 microns for best (1) and average (2) solutions. Valid Range: 0 to 1

Optical_Depth_Small_Average_Ocean

Description: AOD for Small Mode of Average Solution at 7 bands 0.47, 0.55, 0.66, 0.86, 1.24, 1.63, and 2.13 µm. Valid Range: -0.05 to 5.0

Optical_Depth_Small_Best_Ocean

Description: Aerosol Optical Thickness for Small Mode of Best Solution at 7 bands 0.47, 0.55, 0.66, 0.86, 1.24, 1.63, and 2.13 µm. Valid Range: -0.05 to 5.0

Ångström Exponent

The Ångström Exponent is often used as a qualitative indicator of mean particle size. As a rough guideline Ångström Exponent values in the range of 2 indicate small particles which might be associated with pollution or biomass burning. Values in the range of 1 or less indicate the presence of large particles such as sea salt or dust. For the MODIS algorithm Ångström Exponent is not a true measurement but is a derived value.

Angstrom_Exponent_1_Ocean

Description: Angstrom Exponent for 0.55 and 0.86 µm
Dimensions: (Solution_Ocean, Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -1.0 to 5.0

In Collection 6, the preliminary estimated error for angstrom_exponent_1 is 0.45; pixels with an AOD > 0.2 are expected to have a more accurate angstrom exponent.

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: -1.0 to 5.0

Angstrom_Exponent_Land
Description: Angstrom Exponent at 0.47 and 0.67 µm
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -1.0 to 5.0

Other useful parameters

Aerosol_Type_Land
Description: This is the aerosol type used in the retrieval. These are defined by location and season. The quantitative properties associated with each model can be found here: https://darktarget.gsfc.nasa.gov/atbd/land-algorithm
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: 1 to 5 (*1 = Continental, 2 = Moderate Absorption Fine, 3 = Strong Absorption Fine,4 = Weak Absorption Fine, 5 = Dust Coarse)*

Solution_Index_Ocean_Small
Description: Solution number index (1 through 4) for small particles. 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 4
Solution_Index_Ocean_Large
Description: Solution number index (5 through 9) for large particles. 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.

Geolocation and Time Parameters

Longitude
Description: Geodetic Longitude
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -180 to +180 degrees east

Latitude
Description: Geodetic Latitude
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -90 to +90 degrees north

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

Solar_Zenith
Description: Solar Zenith Angle, Cell to Sun
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: 0 to +180 degrees

Solar_Azimuth
Description: Solar Azimuth Angle, Cell to Sun
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -180 to +180 degrees

Sensor_Zenith
Description: Sensor Zenith Angle, Cell to Sensor
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: 0 to 180 degrees

Sensor_Azimuth
Description: Sensor Azimuth Angle, Cell to Sensor
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: -180 to 180 degrees

Scattering_Angle
Description: Scattering Angle
Dimensions: (Cell_Along_Swath, Cell_Across_Swath)
Valid Range: 0 to 180 degrees

MODIS and VIIRS SDSs compared:

The table below shows the equivalent SDS names for the MODIS and VIIRS DT products. Not all SDSs exist for both products. Note the differences in capitalization. Also note that VIIRS SDSs are grouped into geolocation_data or geophysical_data folders which must be specified when calling the data. See the "Aerosol Products File Format Basics" subsection of part 3 on page 5 for more information about accessing the SDS data.

MODIS (Collection 6.1)	VIIRS (Version 2)
variables:	**group: geolocation_data**
Longitude	longitude
Latitude	latitude
Scan_Start_Time	
Solar_Zenith	solar_zenith_angle
Solar_Azimuth	solar_azimuth_angle
Sensor_Zenith	sensor_zenith_angle
Sensor_Azimuth	sensor_azimuth_angle
Scattering_Angle	Scattering_Angle
	Glint_Angle
	group: geophysical_data
Land_sea_Flag	Land_Sea_Flag
Aerosol_Cldmask_Land_Ocean	Aerosol_Cldmask_Land_Ocean
Cloud_Pixel_Distance_Land_Ocean	Cloud_Pixel_Distance_Land_Ocean
Land_Ocean_Quality_Flag	Land_Ocean_Quality_Flag
Optical_Depth_Land_And_Ocean	Optical_Depth_Land_And_Ocean
Image_Optical_Depth_Land_And_Ocean	Image_Optical_Depth_Land_And_Ocean
Average_Cloud_Pixel_Distance_Land_Ocean	Average_Cloud_Pixel_Distance_Land_Ocean
Aerosol_Type_Land	Aerosol_Type_Land
Fitting_Error_Land	Fitting_Error_Land
Surface_Reflectance_Land	Surface_Reflectance_Land
Corrected_Optical_Depth_Land	Corrected_Optical_Depth_Land
Corrected_Optical_Depth_Land_wav2p1	
Optical_Depth_Ratio_Small_Land	Optical_Depth_Ratio_Small_Land
Number_Pixels_Used_Land	Number_Pixels_Used_Land
Mean_Reflectance_Land	Mean_Reflectance_Land
STD_Reflectance_Land	STD_Reflectance_Land
Mass_Concentration_Land	Mass_Concentration_Land
Aerosol_Cloud_Fraction_Land	Aerosol_Cloud_Fraction_Land
Quality_Assurance_Land	
Solution_Index_Ocean_Small	
Solution_Index_Ocean_Large	
Effective_Optical_Depth_Best_Ocean	
Effective_Optical_Depth_Average_Ocean	Effective_Optical_Depth_Average_Ocean
Optical_Depth_Small_Best_Ocean	

Optical_Depth_Small_Average_Ocean	Optical_Depth_Small_Average_Ocean
Optical_Depth_Large_Best_Ocean	
Optical_Depth_Large_Average_Ocean	Optical_Depth_Large_Average_Ocean
Mass_Concentration_Ocean	Mass_Concentration_Ocean
Aerosol_Cloud_Fraction_Ocean	Aerosol_Cloud_Fraction_Ocean
Effective_Radius_Ocean	Effective_Radius_Ocean
PSML003_Ocean	PSML003_Ocean
Asymmetry_Factor_Best_Ocean	
Asymmetry_Factor_Average_Ocean	Asymmetry_Factor_Average_Ocean
Backscattering_Ratio_Best_Ocean	
Backscattering_Ratio_Average_Ocean	Backscattering_Ratio_Average_Ocean
Angstrom_Exponent_1_Ocean	Angstrom_Exponent_1_Ocean
Angstrom_Exponent_2_Ocean	Angstrom_Exponent_2_Ocean
Least_Squares_Error_Ocean	Least_Squares_Error_Ocean
Optical_Depth_Ratio_Small_Ocean_0.55micron	Optical_Depth_Ratio_Small_Ocean_0p55micron
Optical_Depth_by_models_ocean	Optical_Depth_By_Models_Ocean
Number_Pixels_Used_Ocean	Number_Pixels_Used_Ocean
Mean_Reflectance_Ocean	Mean_Reflectance_Ocean
STD_Reflectance_Ocean	STD_Reflectance_Ocean
Quality_Assurance_Ocean	
Glint_Angle	
Wind_Speed_Ncep_Ocean	Wind_Speed_GMAO_Ocean
Topographic_Altitude_Land	Topographic_Altitude_Land
Effective_Optical_Depth_0p55um_Ocean	
	Error_Flag_Land_And_Ocean

Level 3 Atmosphere Products Overview

MODIS geophysical global product composites from multiple satellite overpasses are Level 3 products. As of the creation of this guide the VIIRS L3 products are in development. Level 3 MODIS products also contain SDS parameters relating to cloud properties, water vapor and atmospheric profiles. Because these are composite products they contain a variety of statistical summaries.

Statistics for a given measurement might include:

- Simple (mean, minimum, maximum, standard deviation) statistics
- Parameters of normal and log-normal distributions
- Fraction of pixels that satisfy some condition (e.g. cloudy, clear)
- Histograms of the quantity within each grid box
- Histograms of the confidence placed in each measurement
- Histograms and/or regressions derived from comparing one science parameter to another, statistics may be computed for a subset that satisfies some condition

Because these are composite products we strongly caution users to have a full understanding of the product content before attempting to use these products in research investigations! A much more detailed explanation of the level 3 atmosphere products can be found on the MODIS-atmos website. Links are provided in the following table.

Level 3 Atmosphere Products Summary

Product Name	Sensor	Resolution	Product Level	Size/Time
MOD08_D3	Terra	1 Degree	3	Global / 1 Day
MYD08_D3	Aqua	1 Degree	3	Global / 1 Day
MOD08_E3	Terra	1 Degree	3	Global / 8 Day
MYD08_E3	Aqua	1 Degree	3	Global / 8 Day
MOD08_M3	Terra	1 Degree	3	Global / Monthly
MYD08_M3	Aqua	1 Degree	3	Global / Monthly