

Earth Observing System



**Multi-angle
Imaging
Spectro-
Radiometer**

Data Quality Statement for the MISR Level 2 Aerosol Product

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To determine the latest released version of this document, consult the MISR web site
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Which Product Versions Does this Document Cover?

Product Filename Prefix	Version Number in Filename	Brief Description
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1 EXECUTIVE SUMMARY

Information on the Multi-angle Imaging SpectroRadiometer (MISR) aerosol retrieval approach can be found in the Data Product Specification for the MISR Level 2 Aerosol Product ([DPS](#)) and the MISR Level 2 Aerosol Retrieval Algorithm Theoretical Basis Document ([ATBD](#)).

Table 1 – MISR Level 2 Aerosol Quality Designations*

Maturation Level	Definition	Field Names
Validated Stage 3	Uncertainties are estimated from independent measurements representing global conditions.	Aerosol_Optical_Depth
Validated Stage 2	Uncertainties are estimated from widely distributed independent measurements.	Angstrom_Exponent_550_860nm Absorption_Aerosol_Optical_Depth Nonspherical_Aerosol_Optical_Depth Small_Mode_Aerosol_Optical_Depth Medium_Mode_Aerosol_Optical_Depth Large_Mode_Aerosol_Optical_Depth

A global comparison of retrieved aerosol optical depth (AOD) for coincident MISR Level 2, Version 22 (V22) and Aerosol Robotic Network (AERONET) data for 81 sites over 8 years [*Kahn et al.*, 2010] showed that **overall 63% of the MISR AOD retrievals over both land and water fall within the greater of 0.05 or 20% × AOD of AERONET**, with generally better performance over water. Initial assessments of the results from the 4.4 km resolution V23 retrieval algorithm show that the AOD retrievals perform *at least as well* relative to AERONET as V22, and *significantly better* than V22 relative to high spatial density AERONET Distributed Regional Aerosol Gridded Observations Network (DRAGON) deployments [*Garay et al.*, 2017]. Formal validation of the V23 AOD results is ongoing.

Kahn and Gaitley [2015] considered 11 years of MISR V22 particle property information relative to AERONET over a variety of different types of sites. Unlike the direct-sun AOD observations and the derived Ångström exponent, the conditions required for high-quality AERONET retrievals of particle properties dramatically limit the number of MISR-AERONET coincidences, making statistical comparisons challenging. Even so, *Kahn and Gaitley* [2015] found that the *MISR particle property information is suitable for qualitative, regional-to-global-scale aerosol air mass-type mapping*. They further demonstrated that *MISR particle property retrievals are more sensitive to scene conditions than AOD retrievals, and the derived properties are more reliable when the mid-visible AOD is greater than about 0.15*. In comparison with AERONET observations, *the MISR product effectively discriminates small, medium, and large particles*. With respect to single scattering albedo (SSA), *the MISR retrievals show qualitative agreement with AERONET SSA retrievals*. Finally, *the MISR algorithm tends to report non-spherical aerosols in places where they are climatologically expected*, particularly when the AOD is large. Initial assessments with V23 retrievals suggest that the latest version of the algorithm has *similar performance*, but formal validation is ongoing.

* Based in part on published work for Version 22 of the product, plus preliminary work with Version 23 data.



2 TEMPORAL CHANGES AFFECTING THE PRODUCT

2.1 DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The MISR processing stream has been split into two parts – “FIRSTLOOK” and “FINAL” – to accommodate the time dependence of the Terrestrial Atmosphere and Surface Climatology (TASC) and Radiometric Camera-by-camera Cloud mask Threshold (RCCT) ancillary datasets. The TASC contains snow-ice coverage values that are updated on a monthly basis. The RCCTs are updated based on observations within a 3-month period. Rather than delaying processing of all MISR Level 2 and Level 3 data until these datasets are available, FIRSTLOOK products are generated using the TASC from the same month for the previous year and the RCCT from the same season in the previous year. When the updated TASC and RCCT datasets become available, FINAL processing is run. The FIRSTLOOK products are distinguished by the presence of FIRSTLOOK in the filenames, whereas FINAL products do not include any such designation.

2.2 CHANGES IN THE SNOW-ICE MASK SOURCE

A more conservative cloud screening logic is used over scenes identified by the TASC as being snow-ice covered. In order to better distinguish the surface from clouds, the Angular Signature Cloud Mask (ASCM) is employed in addition to the Stereo-Derived Cloud Mask (SDCM), and the Radiometric Camera-by-camera Cloud Mask (RCCM) applied over other surfaces. Information on the snow-ice coverage in the monthly gridded $1^\circ \times 1^\circ$ snow-ice mask in the TASC is derived from the Near-real-time Ice and Snow Extent (NISE) dataset from the National Snow & Ice Data Center (NSIDC). Different versions of NISE data were used to construct the snow-ice mask used throughout the MISR mission (for details on the NISE dataset see <http://nsidc.org/data/nise>). Prior to November 2009, NISE Version 2, which relied on data from the Special Sensor Microwave Imager (SSM/I) on the Defense Meteorological Satellite Program (DMSP) satellites, was used. Starting in November 2009 and continuing through February 2017, NISE Version 4, which used the Special Sensor Microwave Imager Sounder (SSMIS) on the DMSP-F17 satellite, was employed. Beginning in March 2017, the TASC processing uses NISE Version 5, which relies on the SSMIS instrument on the DMSP-F18 satellite.

2.3 CHANGE IN NEAR-SURFACE WIND SPEED SOURCE

On 23 November 2009 the rotating antenna on the SeaWinds scatterometer on the Quick Scatterometer (QuikSCAT) satellite stopped spinning, ending the instrument’s ability to provide daily, near-real-time, near-surface, ocean wind speed vectors. Since the beginning of the MISR mission, winds from the SeaWinds scatterometer had been used to generate $1^\circ \times 1^\circ$ climatologies of monthly mean near-surface ocean wind speeds in the TASC, which provide a lower boundary condition for MISR aerosol retrievals over Dark Water. Starting with the November 2009 TASC, the source for near-surface wind speeds was changed from SeaWinds on QuikSCAT to SSM/I. Analysis of the differences in quality between MISR Aerosol Products computed with the two different input datasets revealed differences of up to about ± 0.02 in the retrieved AOD for AODs



less than about 0.3. There is also a systematic negative bias of up to -0.005 for AODs greater than about 0.6. Additionally, the change from SeaWinds to SSM/I meant that the u- and v-wind vector components of the wind are no longer available because SSM/I retrievals only report the total near-surface wind speed. As only the total wind speed is used in the Dark Water aerosol retrievals, this change does not affect the Aerosol Product, but the u- and v-wind vector components in the TASC are now set to equal values to accommodate this difference.

2.4 TERRA EQUATORIAL CROSSING TIME HISTORY

The National Aeronautics and Space Administration (NASA) Terra Earth Observing System (EOS) satellite carrying MISR and four other instruments was launched into a near-polar orbit on 18 December 1999. The Terra orbit is sun-synchronous with a nominal equatorial crossing time of 10:30 Local Time (LT). However, at the beginning of the mission, the equatorial crossing was closer to 10:45 LT (see **Figure 1**). From 2000 to about 2002 the orbit was slowly adjusted to bring the satellite into a 10:30 LT equator crossing. This 15-minute difference is unlikely to significantly impact the meteorology as observed by MISR, but users should be aware that the change affects the illumination conditions [Davies *et al.*, 2017]. In particular, the amount of sunglint (specular reflection) observed by a particular MISR camera over the ocean will be greater earlier in the mission as the orbit is slightly closer to local noon.

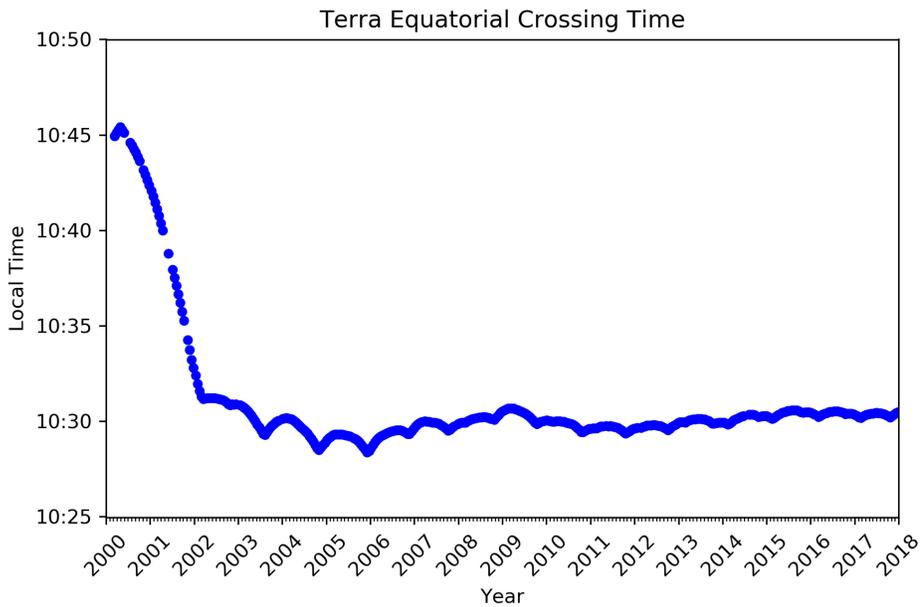


Figure 1. Change in the equatorial crossing time of the Terra satellite from 2000 to 2018.



3 CHANGES IN THIS VERSION OF THE PRODUCT

A significant number of changes have been made in this version of the L2 Aerosol Product that impact the quality and performance of the retrievals. Major changes are summarized in Table 2. Rows in blue indicate the effects are primarily on Dark Water retrievals. Rows in green indicate the effects are primarily on Heterogeneous Surface (Land) retrievals.

Table 2 – List of Significant Changes to the Product

Change	Effect on Product Quality/Performance
Report aerosol retrievals at 4.4 km × 4.4 km resolution [Garay et al., 2017]	Increases coverage, improves AOD agreement with high-spatial resolution AERONET-DRAGON deployments, mitigates underestimate of high AODs over land, better captures AOD maxima and minima [Kahn et al., 2010]
Significant field name and content changes relative to the previous version; please consult the DPS document for more information	Streamlines the product, making it more consistent with other satellite data products and easier to understand
Switch from HDF4, stacked-block format to NetCDF-4 conventional format	Makes product significantly more accessible to widely used software tools and generally easier to use
Provide per-retrieval geolocation and time information	Makes product easier to use
Add additional cloud screening	Mitigates the effects of unscreened clouds, which are more problematic due to the increase in spatial resolution
Add AOD grid points in the look up table below 0.025	Eliminates gap at low AODs observed relative to AERONET [Kahn et al., 2010]
Apply simple veiling light correction to Level 1B2 radiance input [Witek et al., 2017]	Lessens stray light effects within the MISR cameras in high-contrast scenes, reduces AODs retrieved over Dark Water
Add correction factor for the effect of chlorophyll (“underlight”) on MISR red and NIR bands over Dark Water [Limbacher and Kahn, 2014]	Reduces AODs retrieved over Dark Water, improving agreement with AERONET, especially for low AODs.
Where possible, use MISR observations in glint to constrain wind speed over Dark Water, with fall back to TASC [Fox et al., 2007]	Improves representation of lower boundary condition for Dark Water retrievals where applicable
Use inverse summation of absolute chi-squared (χ^2_{abs}) residuals for calculating AOD, AOD uncertainty, and retrieval confidence for Dark Water retrievals [Witek et al., 2018]	Improves retrievals of AOD relative to limited AERONET-maritime aerosol network, improves retrieval uncertainty reporting, introduces additional parameter to assist in cloud screening



Reduce minimum equivalent reflectance uncertainty from 0.04 to 0.0001 [Kalashnikova <i>et al.</i> , 2013]	Improves retrievals of low AODs over Dark Water
Remove log transformation in parabolic fit algorithm	Reduces clustering near AOD grid points in Dark Water retrievals [Kahn <i>et al.</i> , 2010]
Apply only a relative threshold for selecting successful aerosol mixtures over land	Improves coverage over land
Standardize calculation of AOD uncertainty for land retrievals	Provides more consistent uncertainty values
Fix in logic for application of variance thresholds in angle-to-angle correlation tests	Improves coverage over land
Change to camera selection logic	Improves coverage over mountainous regions
Reduce AOD upper bound surface albedo threshold from 0.015 to 0.000	Improves coverage over very dark land surfaces

4 KNOWN ISSUES WITH THE PRODUCT

As it must be run for the entire global MISR data stream, the L2 Aerosol retrieval algorithm attempts to compromise among retrieval accuracy, coverage, and efficiency. Prior to launch, sensitivity studies were performed that provide guidance regarding the optimal performance of multi-angle retrievals from MISR [Kahn *et al.*, 1997; 1998; 2001]. These authors found the following:

- Under good, but not necessarily ideal, retrieval conditions, the MISR observations contain information capable of distinguishing three to five size groupings, two to four categories of SSA, and spherical versus non-spherical particles.
- The information contained in the MISR observations diminishes when the total mid-visible AOD is below about 0.15 and the range of scattering angles is reduced by sunglint or geometric effects.
- Particle property retrievals are more reliable over Dark Water, and retrieval sensitivity degrades with increasing scene brightness.
- Individual component particles must make up about 20% of the total column AOD in order to be retrieved.

These conclusions have been bolstered by subsequent studies using actual MISR observations as well as further sensitivity studies. Interested readers are invited to consult Kahn *et al.* [2010] and Kahn and Gaitley [2015], both of which review a large number of studies related to MISR aerosol retrievals. Note that higher resolution and higher accuracy retrievals than those available from the L2 Aerosol Product are possible using research-quality algorithms, though these must be performed manually, on a case-by-case basis [Limbacher and Kahn, 2014; 2015; 2017].



A number of issues and practical limitations of the operational MISR L2 Aerosol Product are listed in Table 3. Note that this list is not exhaustive and users may encounter other issues from time to time. In these situations, they are encouraged to contact User Services at the Atmospheric Science Data Center (ASDC), NASA Langley Research Center (LaRC): support-asdc@earthdata.nasa.gov.

Table 3 – List of Known Issues and Practical Limitations

Issue or Limitation	Description
Camera artifacts in high-contrast scenes	The simple veiling light correction does not account for the full range of artifacts that may be present in the MISR cameras. These are particularly evident in high-contrast scenes [Limbacher and Kahn, 2015; Witek et al., 2017].
Cloud screening – unresolved or unscreened clouds	Although multiple cloud screening algorithms are applied to the MISR aerosol retrievals, some clouds may be missed or otherwise unresolved by the algorithms, typically resulting in high biases in the retrieved AOD [Witek et al., 2013].
Cloud screening – thin cirrus	Optically thin (< 0.3) cirrus clouds are difficult to screen without eliminating other types of aerosols, such as dust and smoke plumes. Thin cirrus contamination can appear as bands of enhanced non-sphericity due to the multi-angle light scattering of cirrus particles [Pierce et al., 2010; Kalashnikova et al., 2013].
Cloud screening – thick plumes	Optically thick plumes will often be identified as clouds by the cloud screening algorithms. Although the current Aerosol Product allows users to inspect retrievals with less strict cloud screening (see the DPS), in some cases these retrievals are still screened even with minimal cloud screening applied and, therefore, cannot be recovered.
Residual calibration effects	MISR Level 1B2 radiances are corrected using bi-monthly observations of Spectralon calibration panels. Small, residual calibration artifacts may remain, including variation across the camera field of view and slow temporal variations in the absolute calibration [Limbacher and Kahn, 2015; 2017].
Poor retrievals over ice and snow	Retrievals over ice and snow surfaces are adversely affected by the high surface reflectance and low spatial variability, leading to anomalously high retrieved AODs. For this reason, retrievals over Greenland and Antarctica are screened in the user fields, but can be examined in the “raw” auxiliary fields (see the DPS).
No AOD retrievals for values greater than 3.0	The current look up table (LUT) used for MISR aerosol retrievals, the Simulated MISR Ancillary Radiative Transfer (SMART) allows a maximum AOD at 550 nm of 3.0. In cases with AOD > 3.0, the retrieval will either fail or underestimate the actual AOD.
Limited aerosol mixtures	The aerosol mixtures in the SMART currently represent 74 possible combinations of up to three of eight “pure” particle types [Kahn and Gaitley, 2015]. Comparisons with AERONET, other satellite, and field data have shown that this mixture set is not rich enough to account for the full range of naturally appearing aerosols [Kahn et al., 2009; 2010; Kahn and Gaitley, 2015]. Dust model assumptions and limitations are discussed in Kalashnikova and Kahn [2006] and Kalashnikova et al. [2013].



5 TOOLS FOR WORKING WITH THE PRODUCT

The new NetCDF-4 format of the MISR L2 Aerosol Product is compatible with HDF5. This means that the product can also be read by invoking the appropriate NetCDF libraries in various programming languages, such as Python, C++, or R. A simple to use, Java-based viewer called Panoply is available for Mac OSX, Windows, and Linux from the NASA Goddard Institute for Space Studies at (<http://www.giss.nasa.gov/tools/panoply/>). Files can also be browsed using another Java-based tool, HDFView, from the HDF Group (<http://support.hdfgroup.org/products/java/hdfview/>).

Please note that some legacy MISR tools, including `misr_view` (http://eosweb.larc.nasa.gov/project/misr/tools/misr_view) and the MISR INteractive eXplorer (MINX, <http://github.com/nasa/MINX>), do not currently work with new NetCDF-4 files.



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7 Appendix

7.1 ACRONYM LIST

AERONET	Aerosol Robotic Network
AOD	Aerosol Optical Depth
ATBD	Algorithm Theoretical Basis Document
ASCM	Angular Signature Cloud Mask
ASDC	Atmospheric Science Data Center
DMSP	Defense Meteorological Satellite Program
DPS	Data Product Specification
DRAGON	Distributed Regional Aerosol Gridded Observations Network
EOS	Earth Observing System
HDF	Hierarchical Data Format
JPL	Jet Propulsion Laboratory
L2AS	Level 2 Aerosol/Surface
LaRC	Langley Research Center
LT	Local Time
LUT	Look Up Table
MISR	Multi-angle Imaging SpectroRadiometer
NASA	National Aeronautics and Space Administration
NISE	Near-real-time Ice and Snow Extent
NIR	Near-infrared
NetCDF	Network Common Data Format
NSIDC	National Snow & Ice Data Center
QuikSCAT	Quick Scatterometer
RCCT	Radiometric Camera-by-camera Cloud mask Threshold
RCCM	Radiometric Camera-by-camera Cloud Mask
SDCM	Stereo-Derived Cloud Mask
SMART	Simulated MISR Ancillary Radiative Transfer
SSA	Single Scattering Albedo
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
TASC	Terrestrial Atmosphere and Surface Climatology
V22/V23	Version 22/Version 23

