MISR Level 2 Aerosol/Surface Products Quality Statement July 01, 2014

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section 1: MISR Level 2 Aerosol Product
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section 2: MISR Level 2 Land Surface Product
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Quality Designations:

- **Stage 3 Validated:** AEROSOL - aerosol optical depth over heterogeneous surfaces and dark water. LAND - HDRF, DHR, BHR
- **Stage 2 Validated:** AEROSOL - aerosol Angstrom exponent, aerosol single-scattering albedo, AOD due to small, medium, large, spherical, non-spherical particles; LAND - NDVI, LAI and FPAR (excluding needleleaf forest), MRPV (BRFModParam), BHRPAR, DHRPAR

Please bear in mind *that products designated as anything less than "Stage 3 validated" may change significantly between versions.*

MISR maturity level definitions

The statements here apply to **MISR Level 2 Aerosol Products, Version F12_0022 or greater**, and to **Land Surface Products, Version F07_0022 or greater**, effective until further improvements to MISR software are made. See the Versioning Page for an in-depth explanation of the differences among MISR product versions. Older revisions of this quality statement are available through links at the end of this document.

The evaluation of product quality and algorithm refinement are ongoing, as additional validation data are collected and analyzed. Please read and take seriously the summary words of caution, if you have not done so already.

The MISR Level 2 Aerosol/Surface software, which generates the current products, is believed to be functioning well, except as noted below. This statement highlights major known problems and issues with the products, as well as planned upgrades that are not yet implemented. A description of the MISR Standard Aerosol Retrieval algorithm itself is given by *Martonchik et al*, [2009] and references therein.

Aerosol | Land

Differences between "FIRSTLOOK" and "FINAL" processing

The MISR processing stream is split into two parts, "FIRSTLOOK" and "FINAL." The FIRSTLOOK products are generated using the Atmospheric and Surface Climatology (TASC) and Radiometric Camera-by-Camera CloudMask Thresholds (RCCT) ancillary datasets for the corresponding time period of the previous year. For the FINAL products, the MISR radiances are reprocessed using new TASC and RCCT values unique to the time period of the MISR observations. The reprocessing takes place some time after the MISR radiances are acquired, when the new TASC and RCCT data become available.

The TASC dataset contains snow-ice cover and ocean surface wind speed values that are updated on a monthly basis, and the RCCM Thresholds are derived from the observations for a given 3-month period. Therefore, these datasets cannot be generated until the end of the month or season. Rather than delaying all MISR Level 2 and Level 3 processing until these datasets are available, the Level 2 and Level 3 data are produced twice. The FIRSTLOOK products are distinguished by the presence of "FIRSTLOOK" in the filenames; the FINAL products use the original filenames.

Change in cloud mask, starting July 01, 2014

On July 1, 2014, beginning with MISR orbit 77308 updates were made to the TC_CLASSIFIERS product (see TC_CLASSIFIERS Quality Statement). Beginning on this date, both FIRSTLOOK and FINAL MISR L2AS products will use information from the updated TC_CLASSIFIERS product as input. This change only affects the Angular Signature Cloud Mask (ASCM), which is one part of the aerosol cloud screening procedure (see 1.6 Cloud Screening, below). The cloud-masking logic used in the MISR L2AS aerosol retrievals restricts the use of the ASCM to the polar regions, where the ASCM can help distinguish snow and ice from clouds. The updated version of the TC_CLASSIFIERS product now uses the TC_CLOUD product as input, rather than TC_STEREO. This increases the overall coverage of the ASCM, particularly in the polar regions. An examination of one month of data (July 2007) showed that the use of the updated TC_CLASSIFIERS has a negligible impact on the content of the MISR L2AS aerosol product. Sampling change over land was less than 0.1% with no change over water. Less than 0.1% of the retrievals showed any change with the use of the new TC_CLASSIFIERS product.

Change in wind speed source, starting November 23, 2009

On November 23, 2009, the QuikSCAT real-time data antenna failed, which ended the instrument's mission. Therefore, beginning with the November 2009 TASC, the source for wind speeds has been changed from QuikSCAT to the Special Sensor Microwave/Imager (SSM/I). This change affects the MISR L2AS aerosol retrievals over water only. Analysis of the differences in quality between MISR Aerosol products computed from a TASC dataset generated using QuikSCAT winds and one using SSM/I reveals differences of up to about +/- 0.02 in retrieved aerosol optical depth for very low optical depth (below about 0.3). There is a systematic negative bias of up to -0.005 for optical depths greater than about 0.6 when SSM/I are used for the wind speed, compared with QuikSCAT. Ocean surface winds reported in the TASC dataset contain both u (zonal) and v (meridional) components. However, aerosol processing requires only the scalar speed, computed as sqrt(u^2+v^2). Unlike QuikSCAT, SSM/I provides only the scalar wind speed. To flag this condition, the u and v components in the TASC data generated from SSM/I data are set to equal values.

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1. MISR Level 2 Aerosol Product (a.k.a. AS_AEROSOL, MIL2ASAE)

[This product is generated by the MISR PGE9 executable code]

The MISR Aerosol Product is reported over 17.6 km regions, using data from up to 36 channels in a 16 x 16 array of 1.1 km radiance pixels. Algorithm pre-processing executes a range of data-screening operations, and provided a minimum number of pixels pass all the tests, an aerosol retrieval is performed [*Martonchik et al.*, 2009; *Kahn et al.*, 2009a]. Different retrieval approaches are used over land and water, as discussed in the references cited. Detailed validation of MISR-retrieved aerosol optical depth has been performed, and aerosol microphysical property validation is underway, as described below.

1.1 MISR Aerosol Product Maturity

Status	Parameter
Stage 3 Validated	RegBestEstimateSpectralOptDepth, RegMeanSpectralOptDepth
Stage 2 Validated	Reg*AngstromExponent, Reg*SpectralSSA, Reg*SpectralOptDepthFraction

Product users should be aware that the aerosol optical models used in the retrieval analyses provide a practical means of deriving optical depth, and ***optical depth has been validated***, as described below. However, it is more difficult to obtain reliable ground truth data to compare with MISR total column aerosol type (particle microphysical property) retrievals; ***validation of retrieved particle microphysical properties is continuing***, using a combination of AERONET sun photometer [e.g., *Kahn et al.*, 2010] and detailed field campaign data [*e.g., Kahn et al.*, 2009b]. As the MISR retrieval process matures, the aerosol component and mixture optical models will be refined, and the thresholds used in the algorithm acceptance criteria will be further reduced, yielding more tightly constrained results.

The **Stereo Height** parameter in the MISR Level-2 Cloud Stereo product may be of interest to MISR aerosol product users as well. It gives stereo-derived heights of clouds and aerosol plumes to about 0.5 km accuracy in the vertical, whenever elevated features are distinct in multiple MISR views [*Kahn et al.*, 2007a]. For aerosols, this occurs most frequently in aerosol desert dust, wildfire smoke, and volcanic ash source regions, [e.g., *Mims et al.*, 2009; *Val Martin et al.*, 2010]. The spatial coverage provided by MISR stereo imaging complements the greater sensitivity to thin aerosol layers but much more limited spatial coverage of CALIPSO lidar [*Kahn et al.*, 2008].

Regarding algorithm performance in specific cases, some useful diagnostics included in the MISR L2AS Aerosol are listed below. For more information, refer to the MISR Data Product Specifications Document, Rev. S, September 20, 2010 (PDF), the MISR Level 2 Aerosol Retrieval Algorithm Theoretical Basis document (PDF), and *Kahn et al.* [2009a].

Aerosol algorithm performance diagnostics

Parameter name	Grid name (resolution)	Description
RegClassInd	RegParamsAer (17.6 km)	Indicates when a location is eliminated due to solar geometry (1), topographic complexity (2), or no applicable 1.1 km pixels (4). A value of clear (0) means the location was not eliminated for one of the aforementioned reasons; but could still be eliminated for other reasons as indicated by RetrAppMask. Where RegClassInd is (0) or (4), RetrAppMask must be inspected to determine why a retrieval is not attempted. The value "cloudy_region" (3) is not used in RegClassInd.
RetrAppMask	SubregParamsAer (1.1 km)	Indicates reasons why individual 1.1 km pixels are eliminated from input to the aerosol retrieval algorithms. This is based on a cascade of tests (glitter-contaminated, topographically complex, cloudy, etc.); the first test to fail (if any) in the standard sequence is reported in this mask. A certain number of 1.1 km pixels within a 17.6 km retrieval region must pass all the tests for the algorithm to perform an aerosol retrieval on that retrieval region.
AlgTypeFlag	RegParamsAer (17.6 km)	Reports whether the dark water algorithm (1) or heterogeneous land algorithm (3) was used for the aerosol retrieval.
AerRetrSuccFlag	RegParamsAer (17.6 km)	Reports whether aerosol retrieval is successful or not.
NumSuccAerMixture	RegParamsAer (17.6 km)	Number of successful mixtures.
NumCamUsed	RegParamsAlgDiagnostics (17.6 km)	Number of cameras used in the aerosol retrieval.
NumEofUsed	RegParamsAlgDiagnostics (17.6 km)	Number of empirical orthogonal functions (EOFs) used by the heterogeneous land algorithm. Not applicable to dark water algorithm.
ChisqAbs, ChisqGeom, ChisqSpec, ChisqMaxdev, ChisqHet, ChisqHomog	RegParamsPerMixture (17.6 km)	Results of chi-squared tests for each mixture.

1.2. Aerosol Optical Depth

Available at Stage 3 Validated Quality Level

The best estimate of aerosol optical depth (RegBestEstimateSpectralOptDepth) and the average over the optical depths of all successful aerosol models (RegMeanSpectralOptDepth) are Stage 3 Validated maturity level for Version 22. This applies to aerosol optical depth over ***both water and land***, which are produced using different retrieval approaches [*Martonchik et al*, 2009, and references therein].

[Note: For Aerosol algorithm V3.2 (aerosol product 0016) and earlier, RegBestEstimateSpectralOptDepth has been the same as RegMeanSpectralOptDepth. In V3.3 (aerosol product 0017) and higher, if RegMeanSpectralOptDepth is missing, RegBestEstimateSpectralOptDepth will be filled in with the average of successful RegMeanSpectralOptDepth in a 3x3 patch of 17.6 regions, and the standard deviation of this quantity will be reported as the RegBestEstimateSpectralOptDepth uncertainty. These cases are identified by a value of 2 in RegBestEstimateQA.]

A global comparison of retrieved aerosol optical depths for coincident MISR and AERONET data was performed for the time period December 2000 through November 2002 [*Kahn et al.*, 2005a; 2010], The comparison shows that retrieval statistical accuracy compared to AERONET varies with retrieval conditions and expected aerosol type, and overall, 63% of the MISR-retrieved aerosol optical depth (AOD) values in the green band fall within 0.05 or 20% * AOD of AERONET, and about 40% are within 0.03 or 10% * AOD. As expected, correlation coefficients are highest for maritime cases (~0.9), and lowest for bright desert sites (still greater than ~0.7). This PDF document of tables shows uncertainties as a function of wavelength, and binned by season and expected aerosol air mass type, as described in *Kahn et al.* [2005a; 2010].

Note that there is a gap in MISR-retrieved mid-visible AOD for corresponding AERONET values below about 0.02, and some quantization noise in the MISR V22 product [*Kahn et al.*, 2009a; 2010]. These will be fixed in the next version of the MISR aerosol product. MISR underestimation of AOD for AOD values higher than about 0.4 has been traced to several factors [*Kahn et al.*, 2005a; 2010], and possible fixes to these issues are currently under investigation.

Additional MISR optical depth validation, yielding similar results, has been performed over bright deserts [*Martonchik et al.*, 2004; *Christopher and Wang*, 2004; *Kalashnikova and Kahn*, 2006; *Kahn et al.*, 2009b], over the continental United States [*Liu et al.*, 2004; 2007; *Chatterjee et al.*, 2010], over coastal water [*Redemann et al.*, 2005; *Schmid et al.*, 2003; *Reidmiller et al.*, 2006], over biomass burning sites [*Chen et al.*, 2008], over north India aerosol pollution [*DiGirolamo et al.*, 2004; *Dey and Di Girolamo*, 2010], for cirrus situations over dark water [*Pierce et al.*, 2010], and using sun photometer data to evaluate MISR and MODIS results over land and water [*Abdou et al.*, 2005]. The impact on MISR and MODIS retrieved AOT and aerosol properties of algorithm surface boundary condition and particle property assumptions, calibration, sampling, and other factors over dark water is given in *Kahn et al.* [2007b; 2009a].

1.3. Aerosol Micro-physical Property Product Quality

1. Based on the combination of detailed field campaign and other case studies, and initial statistical comparisons with AERONET data, we have a qualitative sense of the particle property information content of the MISR Standard Product, versions 18-22.

2. The formal statistical assessment of the global V22 aerosol product is included in the current quality statement [*Kahn et al.*, 2010].

3. Validating MISR column-effective particle property retrievals is much more difficult than validating column aerosol optical depth (AOD), because, except for sampling differences, the global AERONET sun photometer data can be used as ground truth for the satellite AOD and spectral AOD retrievals, from which column-effective Angstrom Exponent (ANG) can be derived. For other particle properties, the sun photometer results entail additional uncertainties common to other remote sensing aerosol property retrievals. As such, verification of single-scattering albedo (SSA), particle shape, and actual particle size distribution, to the extent possible, is obtained primarily from coincident in situ data taken during field campaigns such as SAFARI 2000 [*Schmid et al.*, 2003], ACE-Asia (*Kahn et al.*, 2004), CLAMS (*Redemann et al.*, 2005; *Reidmiller et al.*, 2006), INTEX-A (*Russell et al.*, 2007), and SAMUM (*Kahn et al.*, 2009b), and from retrieval sensitivity analyses focused on specific particle types, such as non-spherical dust (*Kalashnikova and Kahn*, 2006), spherical, absorbing and non-absorbing (biomass burning) particles (*Chen et al.*, 2008), and thin cirrus [*Pierce et al.*, 2010].

4. The following was predicted in pre-launch sensitivity studies (*Kahn et al.*, 1997; 1998; 2001a) and with subsequent theoretical sensitivity studies; and verified, to the extent possible, in case studies using a combination of the MISR Standard and Research aerosol retrieval algorithms (see references cited in (3) above):

    4.1. Under good, but not necessarily ideal, retrieval conditions, the MISR data contain the information needed to distinguish about three-to-five size groupings, two-to-four groupings in SSA, and at least two groupings in particle shape (spherical vs. non-spherical).

    4.2. Information about particle properties in the MISR data diminishes significantly when the total column mid-visible AOD is below about 0.15 or 0.2, and as the range of scattering angles covered by the MISR cameras is reduced, e.g., due to sun glint or solar geometry.

    4.3. Particle property retrievals are most reliable over dark water. Retrieval sensitivity degrades over brighter surfaces, and as scene variability, on scales of about 1 to 20 km, increases.

    4.4. For MISR retrievals to distinguish the properties of individual component particles within the atmospheric column, they must comprise at least about 20% of the total column AOD.

5. The MISR Standard algorithm must strike a compromise among retrieval accuracy, coverage, and processing efficiency, as it must be run for the entire global data stream. As such, the Standard Product results can approach, but do not always achieve, the performance demonstrated in case study validation (see (4) above). Preliminary statistical results, based on comparisons between MISR V22 and coincident AERONET particle property retrievals (*Kahn, et al.*, 2010), as well as case studies, indicate that:

    5.1. The spherical vs. non-spherical particle distinction is the most robust property retrieval result in the V22 product. This conclusion does not hold for coarse-mode dust (which can be especially important near dust sources), due to the lack of a satisfactory optical model for such particles (*Kalashnikova and Kahn*, 2006). Cirrus contamination of the non-spherical dust signal also occurs, but the possible future inclusion of one or two cirrus optical models in the retrieval would resolve this issue in some circumstances [*Pierce et al.*, 2010].

    5.2. Particle size and Angstrom Exponent (ANG) retrievals show mixed results in the V22 product, with two or three size bins identified under good retrieval conditions [*Kahn et al.*, 2010]. Situations where the aerosol load is dominated by small or large particles are generally identified in the MISR retrieval results, though quantitative agreement is not reliably achieved. This is in part due to the lack of wavelengths longer than 867 nm, which precludes sensitivity to the micro-physical properties of particles larger than about 2.5 microns in diameter. Systematic agreement between the MISR-product and the validation size parameters depends not only on total-column AOD and surface type, but also on the diversity of aerosol component properties in the column, and, not surprisingly, on the range of scattering angles available. This is especially true over dark water, where sun glint can eliminate several view angles, and only two spectral channels of data are used, to minimize surface contributions to the measured radiances. In the V22 algorithm, the available range of mixtures containing components of different sizes imposes additional limitations on retrieved size parameter accuracy in situations where the information content of the radiance data is high.

    5.3. MISR SSA retrievals cannot be considered quantitative. This is due in part to limitations in the range of components and mixtures available in the V22 algorithm, and in part to limited information content in the MISR data itself (*Chen et al.*, 2008; *Kahn et al.*, 1998; 2010). However, qualitative SSA distinctions can be made, and preliminary results often show expected correspondences between absorbing particles, such as smoke, and retrievals that include lower-SSA particles, when minimum AOD and surface quality conditions are met (see (4) above). Due to limited components and mixtures in the V22 algorithm, retrieved SSA is generally high, and AOD retrievals are skewed low, where very dark particles are present, such as over northern India and eastern China [*Kahn et al.*, 2009a; *Dey and Di Girolamo*, 2010].

5.4. In general, AOD retrieval accuracy is maintained at medium and low AOD, even when particle property information is poor, as might be expected from the multi-angle retrievals (*Kahn et al.*, 2005a; 1998).

6. Significant improvements to the MISR Standard particle property retrieval results can be expected in future versions of the product, as upgrades to the algorithm are identified and implemented. Among the upgrades in standard algorithm particle types under consideration, based largely on recent field measurement results, are: the addition of medium, spherical particles, a broader range of spherical absorbing particles, and mixtures of spherical, absorbing smoke analogs with non-spherical dust.

7. Given the limitations in MISR aerosol property product information content, and variable sensitivity depending on conditions, aerosol air mass type, a classification based on the aggregate of retrieved particles properties, appears likely to provide a more robust result than the retrieved quantities individually (*Kahn et al.*, 2001a; 2009). Exploratory work aimed at identifying and systematically flagging situations where particle property information is limited, and at producing an aerosol-air-mass-type classification within the MISR product, is currently underway.

1.4. Dependence on Aerosol Climatology Product (ACP)

The quality of the aerosol product depends upon the quality of the Aerosol Climatology Product (ACP). The ACP contains assumed component aerosol particle properties, and mixtures of these components. For each 17.6 km region, the retrieval algorithm selects *all* mixtures in the ACP that produce spectral-angular radiances in a forward radiative transfer model that meet a set of chi-squared criteria [*Martonchik et al.*, 1998; 2009; *Kahn et al.*, 2009a; *Diner et al.*, 2001; 2005]. The number of mixtures that pass the chi-squared test criteria is reported in the Aerosol Product as "NumSuccAerMixture". The "AerRetrSuccFlag" also reports whether any mixtures met the success criteria (a value of "7"), as well as other possible algorithm conditions (See: MISR Data Product Specifications Document, Rev. S, September 20, 2010, (PDF) p. 166-167).

[If you need to know the actual chi-squared thresholds and other parameters used for a given run of the algorithm, these are reported as configuration parameters in the "Annotation text", which is stored in the Aerosol Product hdf files. For example, there is a sub-section in this text called "(2) Parameters that apply to the dark water aerosol retrievals," in which the threshold choices for the chi-squared absolute, geom, spec, and maxdev tests are reported. A description of the dark water tests themselves is given in *Kahn et al.*, (1998; 2001b). The corresponding heterogeneous land aerosol retrieval chi-squared threshold values are given in "(4) Parameters that apply to heterogeneous aerosol retrievals," and are documented in *Martonchik et al.*, (1998; 2009). See also the MISR Level 2 Aerosol Retrieval ATBD (PDF)].

The ACP was updated in product **Version 0016**, with a new aerosol component dataset and a new mixture dataset. The changes involve ***adding spherical pollution and biomass burning particle analogs having lower single-scattering albedo*** than available in the previous version [*Kahn et al.*, 2005a; *Chen et al.*, 2008], ***more realistic mineral dust*** analogs [*Kalashnikova et al.*, 2005], and a ***richer set of bi-modal and tri-modal mixtures***. It was updated again in Version 0019, when several medium-mode spherical components were removed, and a large spherical component was added [e.g., *Kahn et al.*, 2010]. Refer to the ACP quality statement for further information. Further refinement of the ACP may be expected, based on continuing analysis of field campaign and coincident surface network measurements.

1.5 Dependence on Terrestrial Atmosphere and Surface Climatology (TASC)

The MISR TASC (Terrestrial Atmosphere and Surface Climatology) dataset provides monthly, global climatological information on conditions of the area being observed by the MISR instrument, used during the aerosol retrieval process. Included are ***surface pressure*** for evaluating top-of-atmosphere Rayleigh scattering radiance contributions, climatological ***ozone and water vapor*** for minor spectral band corrections, and ***near-surface wind speed*** to estimate ocean surface white cap area for the lower boundary condition over dark water. [See also the MISR Level 2 Aerosol Retrieval ATBD (PDF) and Ancillary Products and Datasets ATBD (PDF)]. The near-surface wind speed and snow-and-ice-cover mask are now updated between the FIRSTLOOK and FINAL versions of the aerosol product, using time-period-specific observations (as described in the Introduction section above).

1.6 Cloud Screening

Cloud screening is performed prior to the aerosol retrieval on a 1.1 km x 1.1 km pixel basis. The MISR Standard Products include three separate MISR-derived cloud Masks:

- RCCM - Radiometric Camera-by-camera Cloud Mask in the "Level 1B" product [*Zhao and Di Girolamo*, 2004; *Yang et al.*, 2007].
- SDCM - Stereo-Derived Cloud Mask in the "Level 2 TC-STEREO" product [*Moroney et al.*, 2002].
- ASCM - Angular-Signature Cloud Mask in the "Level 2 TC-CLASSIFIERS" product [Di Girolamo and Wilson, 2003].

These three cloud-mask products are used in the aerosol pre-processing according to the logic described by the "cloud_mask_decision_matrix" listed in the MISR Level 2 Aerosol Retrieval ATBD (PDF), section 3.3.8.2.6. Additional cloud screening is performed by radiance angular smoothness and spatial correlation tests that are internal to the aerosol retrieval algorithm. These tests are described by *Martonchik et al.* [2002; 2009].

Each of the 256 1.1 km subregions within the 17.6 km aerosol retrieval region is screened independently for potential cloud contamination using the cloud masking logic, followed by the smoothness and spatial correlation tests in the pre-processing stage. These tests are performed as a cascade and a pixel is examined until it fails one of the tests. Only the first failure is reported explicitly in the RetrAppMask parameter in the L2 AS_AEROSOL product. [See MISR Data Product Specifications Document, Rev. S, September 20, 2010, (PDF), page 163].

The RCCM, SDCM, and ASCM are being evaluated by the MISR cloud masking team at the University of Illinois at Urbana-Champaign. The logic used to apply these cloud masks within the MISR aerosol retrieval pre-processing has not been formally evaluated. However, extensive tests have been conducted on various MISR scenes to assess the performance of the cloud masking logic. Because of the complexity of the MISR aerosol retrieval algorithm, a decision was made to attempt the retrieval on the maximum number of regions where it might be successful. This provides aerosol retrievals in conditions of relatively thick smoke and dust plumes, which are important research objectives for aerosol scientists. However, this means that the MISR aerosol product is likely to be contaminated by the presence of some types of clouds under certain circumstances.

The influence of sub-pixel clouds on the quality of the RCCM and SDCM cloud masks has been considered in a number of studies [e.g., *Zhao and Di Girolamo*, 2004, 2006; *Genkova et al.*, 2007; *Yang et al.*, 2007]. These studies demonstrate the clear-conservative nature of these masks that is favored for aerosol retrievals. The overall impact of direct sub-pixel cumulus cloud contamination on the MISR-retrieved aerosol optical depth and Angstrom Exponent was examined over tropical oceans in *Zhao et al.* (2009). Their results show ~10% of the aerosol retrievals in their dataset contained small (<5% of a 1.1 km sub-region) cumuli. Since the fractional area of the cloud contamination was tiny, the impact on aerosol retrievals for the contaminated pixels was small: an increase in aerosol optical depth of < 0.02 and a decrease in AE < 0.11. They concluded that a MISR-derived aerosol optical depth climatology over tropical oceans is biased high by no more than 0.002 from direct cumulus contamination.

Optically thin, uniform cirrus is likely to impact the MISR aerosol retrieval because it is not reliably screened in the current cloud-masking logic. This is likely to manifest itself as an increase in the optical depth due to non-spherical particles. The degree to which this occurs is unknown. However, *Dey and Di*

Girolamo (2010) noted that over India and surrounding waters, cirrus contamination was not a major contributor to the spatial and temporal variability in the MISR aerosol properties. Work is underway to assess the impact of thin cirrus and potentially retrieve the presence of thin cirrus as an aerosol component (e.g., *Pierce et al.*, 2010).

Users of the MISR aerosol product who are concerned about cloud contamination are advised to use the RCCM, SDCM, and ASCM cloud masks provided in separate products at 1.1 km (subregion) resolution to perform additional cloud screening. A more restrictive logic than the one currently used in the operational pre-processing may provide higher confidence aerosol retrievals at the expense of geographic coverage. See the Cloud Products Quality Statement for more information regarding the RCCM, SDCM, and ASCM cloud masks.

1.7. Additional Aerosol Optical Depth Retrieval Notes and Issues

1.7.1. Known Retrieval Blunders Over Land

Retrieval blunders sporadically occur for ***terrain types having low spatial contrast, most notably bright deserts and snow/ice*** fields. They are manifested as anomalously large values of optical depth (>2) that appear to be randomly scattered throughout an area. Increased numbers of blunders occur over snow/ice fields as a consequence of inadequate cloud screening. Blunder elimination is a high-priority ongoing task, and a spectral contrast angular-signature cloud mask (ASCM; *Di Girolamo and Wilson*, 2003) is being implemented to help reduce these errors.

1.7.2. Optical Depth Uncertainties Over Land

Estimates of aerosol ***optical depth uncertainty over land*** have been improved by applying more stringent constraints on the heterogeneous land aerosol retrieval algorithm. Previous uncertainty estimates were unduly large due to lack of use of spectral information.

1.7.3. Optical Depth Uncertainties Over Water

As a result of refined MISR low-light-level radiometric calibration, the ***uncertainty in MISR-retrieved aerosol optical depth over dark water has been reduced to about 0.025 at mid-visible wavelengths***, based on preliminary comparisons with near-coincident AERONET sun photometer measurements [*Kahn et al.*, 2005b; *Diner et al.*, 2004; *Kahn et al.*, 2007b]. This represents a 40% improvement for the Version 16 of the aerosol product relative to earlier versions.

1.7.4. Algorithm Updates

The aerosol retrieval algorithms described in the MISR Level 2 Aerosol Retrieval ATBD (Revision E, April 2001) have been modified and improved, based on initial analyses of the data. The next release of this document will include an updated description of these algorithms.

1.7.5. Spectral-angular “Shape Mask” Over Land

Beginning with **Version 0012** of the aerosol and surface products, an algorithm refinement that uses a ***spectral similarity condition in the angular shape of surface HDRF*** has been implemented, based on the idea that for natural surfaces, the angular shape should be fairly similar across the MISR wavelengths [*Diner et al.*, 2005]. This upgrade has resulted in three tangible benefits: (1) far fewer optical depth outliers occur over land, (2) correlations with

AERONET aerosol sun photometer data are quantitatively improved, and (3) the quality of surface products is markedly enhanced.

1.7.6. Technical Note about Uncertainties

The following MISR aerosol fields labeled as uncertainties:

- RegBestEstimateSpectralOptDepthUnc
- RegBestEstimateAngstromExponentUnc

are calculated as the standard deviations of the values retrieved for all aerosol mixtures that pass the acceptance criteria. So these represent the uncertainty associated with the retrieval algorithm sensitivity to differences among the components and mixtures in the algorithms aerosol climatology. Calibration uncertainty figures into the calculation of the chi-squared statistics used in the acceptance tests. See also the MISR Level 2 Aerosol Retrieval ATBD (PDF)].

The following uncertainties are no longer calculated, and should not be used:

- RegBestEstimateSpectralSSAUnc
- RegBestEstimateSpectralOptDepthFractionUnc
- RegBestEstimateNumberFractionUnc
- RegBestEstimateVolumeFractionUnc

2. MISR Level 2 Land Surface Product (a.k.a. AS_LAND, MIL2ASLS)

[This product is generated by the MISR PGE9 executable code]

2.1 MISR Land Surface Product Maturity

Status	Parameter
Stage 3 Validated	LandHDRF, LandHDRFUnc, LandBHR, LandBHRRelUnc, LandBRF, LandDHR,
Stage 2 Validated	BRFModParam1, BRFModParam2, BRFModParam3, BRFModFitResid, NDVI, LAI (excluding needleleaf forest biome type), FPAR (excluding needleleaf forest biome type), BHRPAR, DHRPAR,
Not implemented	BiomeBestEstimateQA

2.2 Aerosol Dependency

The land surface product relies on the aerosol product for atmospheric correction information. Therefore, the quality of the land surface product depends upon the quality of the aerosol product. The atmospheric correction information used in the land surface retrievals is reported in RegSfcRetrOptDepth and related fields in the aerosol and land surface products.

2.3 Reliability of Land Surface Reflectance Values Dependent Upon Aerosol Optical Depth Magnitude

At the current time land surface retrievals, particularly those with low surface albedo, should be considered most reliable when the aerosol optical depths are small (< 0.2). Accordingly, the land surface parameter "LandQA" is set to "bad" (1) where the optical depth is greater than 0.3. For higher albedo areas, such as deserts, good results are obtained for optical depths < 0.4. Other parameters which indicate the quality of the surface retrieval include LandBHRRelUnc (ratio of BHR [Bi-Hemispherical Reflectance] uncertainty to BHR value) and LandHDRFUnc (HDRF [Hemispherical-directional Reflectance Factor] uncertainty), which are derived from the uncertainty in the retrieved aerosol optical depth. It can be assumed that these uncertainty products also apply to the DHR [Directional Hemispherical Reflectance] and BRF [Bidirectional Reflectance Factor] surface products, respectively. Inspection and analysis of these products, for both dark and bright areas, indicates that they adequately represent the uncertainty associated with their respective products, and therefore are good indicators of product quality. Some sporadic but obvious retrieval blunders do occur, however, for areas that are bright and have little contrast (e.g., deserts and snow/ice fields) and these are easily seen in the images as anomalously bright reflectances. Further refinements in the quality of the aerosol retrievals over land are planned for future releases and these are expected to result in improvements in the surface retrieval blunder rate and product quality at larger optical depths.

2.4 Quilting Effect in Land Surface Reflectances

Most of the retrieved land surface reflectances are reported at a 1.1 km x 1.1 km spacing, whereas the retrieved aerosol optical depths are computed at a coarser 17.6 km x 17.6 km spacing. It is assumed that aerosol amount is constant over any particular 17.6 km region, which results in values of aerosol optical depth that are inherently discontinuous going from one region to an adjacent one. Therefore, the atmospheric correction process, using the coarse resolution aerosol data with the fine resolution reflectance data, occasionally produces a distinctive "quilting" effect in the directional surface reflectance imagery, i.e., a discernable block pattern. Imagery from the extreme off-nadir cameras at 446 nm (blue band) is particularly prone to this effect. The aerosol optical depth discontinuities are due to both real variation in aerosol amount on spatial scales smaller than the 17.6 km spacing and to intrinsic uncertainties associated with the aerosol retrieval process. Because of improvements to the land aerosol retrieval algorithm, the resulting inter-regional optical depth variability, much of which was an artifact of the retrieval process, has now been significantly reduced, thus mitigating, to a large extent, the "quilting" effect. The magnitude of any remaining "quilting" effect is well described by the surface reflectance uncertainty parameters, mentioned in the previous section.

2.5 Fill Values in Land Surface Reflectances

Land surface reflectances are computed separately for each MISR spectral band. In some cases, the land retrievals succeed in one MISR band, but not another. This can cause visualization problems when viewing a composite image of land surface reflectances which contains spectral bands for both successful and unsuccessful retrievals. This occasional algorithm failure in certain bands (notably blue and/or red) is a high priority item for investigation and repair.

2.6 Correction to Modified RPV Model BRF Parameters (R0, K, B)

Version 0016 and earlier of the modified RPV (MRPV) model BRF parameters (r0, k and b; a.k.a. BRFModParam1, BRFModParam2, and BRFModParam3) are affected by a software error, which results in incorrect output for those parameters. The error is present at all latitudes, but is most severe (and visually obvious) at geographical regions where MISR is viewing nearly perpendicular to the principal plane (which is within a relatively narrow belt about the equator and about 3-5 blocks wide, shifting latitude-wise with season). This error is corrected in version 0017 and later products.

2.7 Reliability of LAI/FPAR Dependent Upon Land Surface Reflectances

The software which computes leaf-area index (LAI) and fraction of photosynthetically active radiation (FPAR) uses Land Surface Reflectances (BHR and BRF) as input. Two spectral bands, red and near-infrared, and 7 view directions are currently used to produce LAI and FPAR.

The quality and spatial coverage of LAI and FPAR depend on the quality and coverage of the Land Surface Reflectances (BHR and BRF). Surface reflectances whose uncertainties exceed an acceptable level of 20% result in algorithm failure. The data analysis indicates that uncertainties in the MISR BHR of dense vegetations at red and blue spectral bands can substantially exceed the acceptable level. At these wavelengths, dense vegetations exhibit low reflectances. As indicated in section 2.3, reliability of land surface retrievals can be low in this case. High uncertainties in BHR retrievals over dark surfaces, therefore, can result in algorithm failure, reducing the number of successful retrievals. With a probability of about 70%, uncertainties in retrieved LAIs do not exceed uncertainties in the MISR Surface Reflectances (BHR and BRF). Inspection and analysis of the LAI/FPAR product indicate that the successfully retrieved LAI/FPAR values follow regularities expected from physics.

Considerable attention was also paid to characterizing the quality of the LAI/FPAR parameters. The quality of LAI/FPAR retrievals can be assessed through examining LAINumGoodFit1 and LAINumGoodFit2 accompanying the product; that is, LAINumGoodFit1*LAINumGoodFit2>0 indicates highest retrieval quality; LAINumGoodFit1>0 and LAINumGoodFit2=0 - intermediate quality. The operational version of the algorithm does not archive low quality retrievals (LAINumGoodFit1=0 and LAINumGoodFit2>0). For more details on the performance of the provisional LAI/FPAR algorithm as well as how to interpret LAIMean1 and LAIMean2 as a function of biome type, the users is referred to *Hu et al.*, (2003)

2.8 Improved LAI for Grasses and Broadleaf Crops

Validation of version 16 and earlier of the MISR LAI product suggests the algorithm substantially overestimated LAI values in grasses and broadleaf crops. A recalibrated algorithm has been incorporated into version 17 and later. Validation of version 17 suggests the MISR LAI product to correctly accommodate structural and phenological variability. The version 17 product is accurate to within 0.5 LAI in herbaceous vegetation and savannas and is an overestimate by about 1 LAI in broadleaf forests.

2.9 BHRPAR and DHRPAR Availability at Provisional Quality Level

The BHRPAR and DHRPAR fields are now of "Provisional" quality, as explained in this PDF document.

2.10 Some Land Surface Fields Not Available

The following fields in the aerosol product are not currently computed, and contain fill only: BiomeBestEstimateQA.

2.11 LAI/FPAR Availability at Stage 2 Validated Quality Level

The LAI/FPAR [Leaf Area Index/ Fractional absorbed Photosynthetically Active Radiation] fields for version 22 are of "Stage 2 Validated" quality for all biome types except needleleaf forest (which remain at "Provisional" quality level).

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