MISR Level 2 Top-of-Atmosphere/Cloud Products Quality Statement
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Quality Designator:

- **Stage 3 Validated:** Radiometric Camera-by-camera Cloud Mask (RCCM), Stereo Heights, BRFs reregistered to reflecting layer altitude.
- **Stage 2 Validated:** , Winds, Stereoscopic Cloud Mask (SDCM), Angular Signature Cloud Mask (ASCM), Scene Classifiers
- **Stage 1 Validated:** Local, Restrictive, Expansive and Broadband Albedos
- **Provisional:** Support Vector Machine (SVM) Scene Classifiers
- **Beta:** SVM Cirrus Fraction

MISR maturity level definitions

This statement applies to MISR Level 2TC RCCM (F04_0025), Stereo (F08_0017), Classifiers (F06_0011), and Albedo (F05_0011) and beyond until further improvements to MISR software are made. Quality statements covering earlier time periods may be accessed through links at the bottom of this page.

The evaluation of the product quality is on-going. Please read the summary words of caution if you have not done so already.

Many of the algorithms used in the product retrievals have been developed specifically for the MISR instrument, and as such, are relatively untested. Trade-offs with the stereo-matching algorithms have been made at times to sacrifice accuracy or coverage for speed.

In spite of all the warnings, the MISR Level 2 TC Stereo, Albedo and Classifiers software which generated these products is believed to be functioning well except where noted below. This statement highlights major known problems with the products, as well as functionalities which are currently not implemented.

RCCM | Stereo | Classifiers | Albedo

SOFTWARE PORTED TO LINUX AND FINALIZED

All of the MISR software has now been ported over to Linux, and the software that is currently in production is the *Final* version. The entire mission is being reprocessed with the current revision.

The linux port resulted in a very small percentage (0.1%, or 1 in 1000 pixels) of the RCCM pixels being different from the original products. Occasionally, a difference rate of 5-7% can be found in the observable values, but the magnitude of these differences is very small and does not affect the cloud mask itself. When the cloud masks differ, it is only by a single category (i.e. CloudHighConfidence to CloudLowConfidence).

The stereo differences between SGI and Linux are minimal. Occasionally (< 10 pixels per swath) the heights will differ by 1 meter, and it is very rare for these differences to affect the cloud masks.

The effect of the linux port on the ASCM is very small, usually limited to < 5 differences per swath and only by a single category, as with the RCCM. The SVM Classifier has a 1.5x10E-03 % difference or about 1 in 100,000 pixels. As expected with all the cloud masks being so similar, the cloud fractions show very small differences with the port to Linux. About 1 in 100,000 cloud fractions are different, and the mean difference is on the order of 5.0x10E-03.

The difference rate in the albedos (for Local, Restrictive and Expansive) is bounded by 0.02% or 1 in 5000 pixels, with the max differences in the 1.0E-04 range, where the albedos usually range between 0 and 1.

DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The MISR processing stream has now been split up into two parts, "FIRSTLOOK" and "FINAL", to adjust for the new time dependence of the Atmospheric and Surface Climatology (TASC) and Radiometric Camera-by-Camera CloudMask Thresholds (RCCT) ancillary datasets. Both the TASC and RCCT datasets now contain data that is unique to the time period for which the datasets are constructed. The TASC dataset now contains snow-ice and ocean surface wind speed values that are updated on a monthly basis, and the RCCM Thresholds are now 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 processing of Level 2 and Level 3 until these datasets are available, the Level 2 and Level 3 data are now produced twice over. These two different runs are given the names "FIRSTLOOK" and "FINAL". The FIRSTLOOK processing uses the TASC from the same month/previous year and the RCCT from the same season in the previous year. When the updated datasets become available, the FINAL processing which uses the correct RCCT and TASC data is run. The FIRSTLOOK products are distinguished by the presence of the "FIRSTLOOK" in the filenames, the FINAL products use the original names.

L2TC RCCM (a.k.a. GRP_RCCM) (from MISR PGE13)

OVERVIEW

The first cloud mask produced during the MISR data processing is called the Radiometric Camera-by-camera Cloud Mask (RCCM) and it is calculated separately for each camera. It is one of three independent cloud masks generated from MISR data. The other two cloud masks are called the Angular Signature Cloud Mask (ASCM) and the Stereo Derived Cloud Mask (SDCM), neither of which have a camera dependence.

The RCCM algorithm applies traditional spectral and spatial measures to data from each MISR camera in order to produce separate cloud masks for each camera. These measures and the threshold procedures are completely different for the two processing paths: ocean and land. For this reason, ocean and land may carry different quality statements. Another field, the Glitter Mask, is included in the RCCM product for the sake of convenience.

Over ocean, the RCCM employs a static threshold procedure. The static thresholds are a function of the sun-view geometry and have been fine-tuned several times since launch.

The RCCM land thresholds have since been updated so they are now derived on the data from the season. So, the thresholds for data collected in Spring of 2009 will be derived on the actual RCCM observable values for March through May of 2009. The RCCM is now Stage 3 Validated for all scene types.

DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The FIRSTLOOK processing uses the RCCM thresholds from the same season but from the previous year, since we need to process the RCCM in order to generate the thresholds in the first place. After the thresholds are generated for each new season, the RCCM will be regenerated this time using the correct thresholds. This rerun constitutes the FINAL processing. Preliminary studies suggest that about 5% of the cloud mask results will be different between the FIRSTLOOK and FINAL processing. The useage of these new thresholds will aid in the detection of thin clouds.

PRELIMINARY VALIDATION RESULTS

Visual inspection, data from field campaigns, and comparison with other satellite-derived cloud masks have been used for validation. Overall, better than 90% agreement exists between all cloud masks (including the SDCM and ASCM described in this statement) over ice-free ocean and better than 85% agreement is observed for all snow-free land surfaces. This statement will be updated to include more specific numbers when the current validation work is complete.

Although overall performance looks good for the RCCM over ice-free ocean, it does suffer from the traditional problems encountered with spectral/spatial cloud masks:

- Very thin clouds may go undetected.
- Thick aerosol layers may at times be classified as cloud.
- Cloud detection over strong sun-glint regions may at times be a problem.
- Sea ice is often classified as cloud.
- Shallow coastal and inland water can cause clear skies to be classified as cloud.

The Glitter Mask indicates regions of the data that may contain sun-glint. As of February 5, 2002, (version 0011) the sun-glint cone angle was increased from 30 degrees to 40 degrees in order to mask some of the weaker glint that was observed in the imagery.

L2TC Stereo (a.k.a. TC_STEREO) (from MISR PGE8a)

The Stereo Heights are now Stage 3 Validated following improvements in the Wind Quality Assessment flags and numerous comparisons of the stereo heights to ground truth data. The Reflecting Level Reference Altitude (RLRA) is also at this level. This label applies to all products with a version number of F08_0016 or greater. This version of the software went into production on August 01, 2006. The winds themselves progressed to Stage 2 Validated on the same date. The SDCM is Stage 2 Validated for all scene types.

Several factors affect the quality of the stereo heights including the nature of the scene being matched, the co-registration of the different cameras in Level 1, and the accuracy of the wind retrievals.

OVERVIEW

The MISR cloud-top height retrieval is conceptually simple. An object located above the surface (such as a cloud) will appear in two different positions when viewed from different angles. The apparent change in position (parallax or disparity) as measured by pattern- matching software can be used to calculate the cloud height. The cloud motion vectors (winds) are retrieved first using three angles, then the heights are calculated using the disparity measured between two cameras and the knowledge of the winds. [Moroney et al, 2002]

The winds are calculated at 70.4km resolution and are assumed to be constant over the region. Changes in the estimated wind vectors across the domain boundaries lead to a blocky appearance in the heights at the same resolution. The Stereo Heights and Stereoscopically Derived Cloud Mask (SDCM) are calculated at 1.1 km resolution.

The SDCM is directly derived from the corresponding cloud height. If the stereo height is more than 560 m (the resolution of the stereo heights) above the sum of the terrain elevation plus its standard deviation, the pixel is designated as cloudy. The SDCM is unable to detect clouds over land that are below this altitude.

DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The differences between the FIRSTLOOK and FINAL data for the TC_STEREO product are minimal. The wind and preliminary height determination do not use either the SnowIce masks or the RCCM at all so these products are unaffected. If the height retrievail fails over ocean and the RCCM indicates that the area is ClearHC, then the surface height (of the ocean) is inserted in place of the missing stereo height to avoid huge gaps in the stereo height product over ocean. This is the only place in the height retrieval where the RCCM is used. Since the RCCM ocean thresholds are static, the heights and winds are unaffected by the FIRSTLOOK vs. FINAL differences.

The SnowIce masks in the Stereo product are obviously affected by the change in the TASC, and the RCCT changes feed into the Feature-Referenced RCCM, but the overall change in the TC_STEREO product between FIRSTLOOK and FINAL processing is very small.

CLOUD-TOP HEIGHT CATEGORIZATION

With the addition of the WindQA flags to the product, the StereoHeights and all related fields are now produced in three different types - BestWinds, WithoutWinds and RawWinds.

The BestWinds parameters are only computed for those domains where there was a successful wind retrieval of Good or VeryGood quality. They are set to NoRetrieval otherwise. These data comprise our best guess of what the true stereo height is for each pixel. There is still some blockiness present but it is greatly diminished from previous versions of the data. The WithoutWinds data are calculated assuming a constant value of zero wind everywhere. Over clear or motionless areas, the WithoutWinds will equal the actual stereo height, everywhere else they instead yield a "relative height". The blockiness due to wind discontinuity is removed and the relative variation in the heights over small areas is correct.

The RawWinds product uses all available wind retrievals regardless of their quality with a default to zero wind when no wind measurement is available. This is the algorithm used in previous versions of the stereo product. These heights are blocky due to discontinuities and drop-outs in the wind vectors. This is intended as a diagnostic field to allow assessment of the cloud-top height improvement due to the inclusion of the WindQA flags.

EXPECTED ACCURACY

Under good matching conditions with perfect registration (see Registration paragraph below), the winds are consistent with the theoretical limit of 3 m/s with a corresponding height error of 400 m. Difficulties in applying the stereo-matchers to multi-layer or low-contrast scenes limit the accuracy of the winds and heights. The stereo heights themselves are quantized in units of 560 m. The stereo-matchers lack subpixel accuracy and a single pixel of disparity difference translates into 560 m of height. In general, the stereo-matchers are accurate to within one pixel.

WIND VALIDATION RESULTS

The wind retrieval algorithm has undergone major revisions, both in the calculation of the wind vectors themselves and the determination of their associated quality flags. A new "sub-pixel" wind algorithm has been implemented to calculate the wind vectors from the parallax measurements returned by the stereo matchers. Additionally, a new quality measure based on the difference between the winds calculated using the fwd and aft sets of cameras (An-Bf-Df and An-Ba-Da) is included. The coverage of the good quality winds has been reduced to roughly 50%, but we now have greater confidence in the wind quality flags. [Davies et al., 2005

The Goddard Global Modeling and Assimilation Office (GMAO) has performed a detailed analysis of 6 weeks (Sept 1 to Oct 15, 2003) worth of wind data (version F08_0015) by comparing it to the expected streamlines derived from 6 hour forecasts. The winds have been slightly improved since then. Several thousand observations per day were included in this study. The results are tabulated in the wind errors table.

Quality flags for each individual wind vector are included in the TC product. These flags are computed by looking at the signal strength returned from the stereo-matchers and also at the difference between the winds derived from the forward and aft viewing cameras. The flags are set conservatively so it is possible for "good" winds to be labelled as bad, but very few poor quality winds should pass the quality test. An individual wind-vector should only be considered of Validated quality if both Orbit_QA flags indicate "good", the mean misregistration retrievals for the Df and Da cameras (over the entire swath) is zero, and the individual wind-qa flag indicates "good" or "very good". These misregistration retrievals may be cloud-contaminated, so one should look for a modal peak located at +/- one pixel error.

HEIGHT VALIDATION RESULTS

Comparisons between ground-based millimeter-wave cloud radar and lidar measurements of cloud top and MISR stereo-derived cloud top heights have been conducted using data from 3 sites. One site is in the Southern Great Plains (Lamont, Oklahoma), the second in the tropical western Pacific (Nauru Island), and the third at the North Slope of Alaska (Barrow). These radars and lidars are operated as part of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) program.

The MISR height retrieval is performing largely as expected when the clouds are thick enough to be identified by the pattern matchers. A summary of results is presented in the [height errors table](#).

For moderately optically thick clouds (5 > tau > 0.5), which may lack well-defined contrast at the cloud top, the MISR retrievals tend to identify structures within the cloud (typically 500m to 1.5km deep) or different cloud layers lower in the atmosphere. Much of the mean offset shown in these summary statistics result from these moderately thick clouds. This optical depth assessment is based on a variety of retrievals using ground based radar and lidar techniques.

The pattern-matchers used in the stereo height retrievals identify the location of greatest contrast, which is not necessarily the highest point in the cloud. MISR, along with many other instruments, has difficulty in retrieving the height of optically thin clouds. The optical depth threshold at which the algorithm identifies the thin cloud rather than the underlying object depends on the contrast of the underlying feature. The reader should take this inherent limitation of the retrievals into account when comparing MISR heights to other instruments or to model results.

For the extreme case of very dark features (such as open water) near bright features such as snow, clouds with optical depth of at least 2 and perhaps as much as 5 can be missed. When boundary layer clouds such as stratocumulus or trade cumulus are present, cirrus clouds with optical depths of 2 to 5 are sometimes not retrieved. However, for cases without lower clouds or underlying bright surfaces, thin cirrus clouds with optical depths near 0.5 (over heterogeneous land) and perhaps even smaller (over dark water) are usually detected.

STEROSCOPIC CLOUD MASK VALIDATION

The Stereoscopically Derived Cloud Mask (SDCM) is calculated solely from the Stereo Heights. If the height is more than 560m above the terrain, it is called a cloud. It is therefore difficult to detect low clouds close to this altitude. The possible values of the SDCM have been relabelled to Cloud (Low/High Confidence) and Near Surface (Low/High Confidence). There is no additional information available to determine whether a pixel with a low feature height is clear or not. The best we can say is that it's near to the surface. Additional radiometric data must be used to distinguish low clouds and fog from clear sky.

The SDCM cloud/no-cloud distinction over clear-sky ocean is good. If the SDCM says Cloudy, then the likelihood of this being true is estimated to be above 95%. This ties to the fact that the Preliminary SDCM consistently returns NoRetrieval over clear-sky ocean because there are not any features for the pattern-recognition algorithms to match. Any retrieval of the SDCM (be it Cloud or NearSurface) over ocean is likely to be cloud. The SDCM (due to the 560m resolution of the stereo heights) has been observed to over-detect clouds in broken boundary layers. This is noticeable in areas dominated by trade cumulus.

The SDCM comes in four flavours - Preliminary_SDCM (BestWinds), Preliminary_SDCM (WithoutWinds), SDCM (BestWinds), and SDCM (WithoutWinds). The "BestWinds" varieties are calculated using the corresponding BestWinds stereo heights, and similarly for the WithoutWinds data. The Preliminary masks are calculated using only stereoscopically derived heights, while the "final" versions use RCCM data to fill in the missing stereo heights over clear-sky ocean. Cloud shadows falling on top of lower clouds can be mistaken as clear by the RCCM, so this results in an erroneous fill-in of the surface height under these conditions.

The SDCM has been validated using a combination of visual inspection, field campaigns and other satellite-derived cloud masks. Its accuracy is estimated at more than 90% over ice-free ocean, and greater than 85% over other surface types including snow and ice. The SDCM over land has been promoted to Stage 2 Validated based on these results and given its close derivation from the Stereo Heights which are now Stage 3 Validated.

A study of the cloud mask against ARM data for the Nauru and Manus sites in the tropical western Pacific shows that the SDCM can detect clouds with an optical depth > 0.3 to 0.5.

WIND RETRIEVAL QUALITY AND HEIGHT BLOCKINESS

The accuracy of the cloud motion retrieval is a key component in the cloud-top height calculation. The winds are very sensitive to any misregistration of the oblique angles, and discontinuity in the wind vectors shows up as clearly visible "blockiness" in the stereo heights (most noticeably in the RawWinds version of the heights - see next section). Drop-outs in the wind vectors result in a default wind field of zero being applied and this will also appear as blockiness in the RawWind heights. In addition, failure of the stereo-matchers will also cause poor quality winds on occasion.

The present wind retrieval does not differentiate cloud from terrain. An estimated 3 in 5 wind retrievals over land with Quality Flag values of "Good" or "VeryGood" correspond to terrain rather than cloud. All of these retrievals exhibit retrieval heights (relative to the surface ellipsoid) closely corresponding to terrain altitude. Nearly all exhibit wind magnitudes close to zero. Near surface MISR wind retrievals over land must be treated with caution.

REGISTRATION OF LEVEL 1 DATA AND ORBIT QUALITY FLAG

Level 1 now includes an Orbit Quality (Orbit_QA) flag that assesses the registration quality of the orbit based on the Terra orbit attitude and ephemeris data quality indicators. All of the TOA/Cloud products now read in this quality flag. If the flag indicates that the registration quality of the orbit might be poor, all the BestWind height products in the TC_STEREO file are set to NoRetrieval since it is impossible to retrieve good quality winds if the registration is inaccurate. This decision is made on an orbital basis and is flagged in both the Orbit_QA and

CloudMotionSource flags.

Additionally, a new Orbit_QA flag that also measures the registration quality of the entire orbit is now available in the product. This new flag is calculated from the distribution of the fwd-aft wind differences (as mentioned in the Wind Validation paragraph above). A value of -1 for either flag means that the registration of the orbit is suspect. In both cases, the CloudMotionSource flags are set to a value of "1" and all the BestWind Height fields are blacked out. Two other important pieces of file metadata include the mean fwd-aft wind difference as calculated over the entire swath ("Mean_fwd_aft_wind_diff"), and the fraction of domains with an acceptably low wind difference ("Fraction_good_fwd_aft_wind_diff"). Ideally the mean difference should be less than 5 m/s and the fraction of good domains should be more than 0.7.

The co-registration of the Df, Da, Bf and Ba cameras has been improved (significantly so in the case of Da) with the current release of the Level 1 software. See the Georectification Page for more details.

The registration accuracy of the Df and Da cameras in both the along and across-track directions is also reported in the product at 70.4 km resolution. These retrievals generally succeed over clear-sky land, and calculate the misregistration of the D cameras in units of 275 m pixels. There is a known problem with mistakenly calculating a spurious misregistration over cloud-contaminated areas. Thus if one is concerned about individual misregistration retrievals, the oblique views should be checked for cloudiness to ensure that the scene is indeed clear.

MULTI-LAYER SCENES

Multi-layer scenes and those without a great deal of contrast cause problems for the stereo-matching algorithms. The variation in cloud opacity with view angle, in particular, makes the wind retrieval (and therefore accurate height calculation) difficult. In such cases, MISR will match the layer of greatest contrast, rather than the highest heights. High, thin clouds over a lower-level cloud deck are ignored.

ERRORS IN VERSION F08_0014 OF TC_STEREO DATA (NOW CORRECTED)

All the problems described below have been corrected in subsequent versions of the TC_STEREO (F08_0015), TC_CLASSIFIERS (F05_0008) and TC_ALBEDO (F04_0008) products.

A software error was discovered for Version F08_0014 of the TC_STEREO data that results in some missing values for the Winds, BestWind Heights, and BestWind SDCM. About 40% of the orbits showed some missing data, and 5% had more than half of their data missing. The data that is present in the file is accurate. The beginning of the orbit is fine, then either the LowWinds or the HighWinds drop out (along with the corresponding heights and cloud masks) at a certain point in the orbit. The WithoutWinds Heights, associated cloud masks and the RLRA are not affected.

The missing BestWind heights also affect the Feature-Referenced RCCM (FRRCCM), the Feature-Referenced ASCM and the CloudFractions. The Albedo product is minimally affected - the BRF's as registered to the top and sides of the RLRA columns are unchanged, but there may be some small differences in the albedo values themselves due to different modelling co-efficients being applied.

OTHER PROBLEMS

The stereo-matchers lack a robust blunder detection algorithm and will therefore retrieve spurious results on occasion. This results in areas of "noise" in the stereo height field. The scene is pre-screened for sufficient contrast and a failure in this test results in a NoRetrieval in the stereo heights, but sometimes low contrast scenes are matched and will result in difficulties applying the stereo matchers correctly.

Sometimes horizontal stripes of NoRetrieval values will appear in the product. See the Exceptions/Anomalies paragraph in the Level 1 Quality Statement for more details.

DATA SOURCE FLAGS

The Orbit_QA, CloudMotionSource, WindQuality and StereoHeightSource flags all contain key information about the source of the TC_STEREO data. Their values are listed below. The Orbit_QA flag is contained in the global file attributes, the others are available as gridded data fields at the appropriate resolution.

Orbit_QA and Orbit_qa_winds:	-9999.0 = NoRetrieval -1.0 = Poor Registration 0.0 = Nominal Registration
CloudMotionSource:	0 = Stereo Not Attempted 1 = Wind Retrieval Failed due to poor Orbit_QA flag 2 = Stereo Attempted and Failed 3 = Stereo Succeeded for Low Cloud only 4 = Stereo Succeeded for High Cloud only 5 = Stereo Succeeded for Low and High Clouds
WindQuality:	0 = NoRetrieval 1 = Bad 2 = Uncertain 3 = Good 4 = VeryGood

StereoHeightSource:	0 = NoRetrieval
	1 = Stereoscopically Determined height
	2 = Surface Override
	3 = Default Cloud
	4 = MODIS height
Cloud Masks (SDCM):	0 = NoRetrieval
	1 = CloudHighConfidence
	2 = CloudLowConfidence
	3 = NearSurfaceLowConfidence
	4 = NearSurfaceHighConfidence
Cloud Masks (RCCM, ASCM):	0 = NoRetrieval
	1 = CloudHighConfidence
	2 = CloudLowConfidence
	3 = ClearLowConfidence
	4 = ClearHighConfidence
Consensus Cloud Classifier:	0 = NoRetrieval
	1 = Overcast
	2 = KnownCloud
	3 = KnownClear

REFERENCES

The improvements to the winds as of February 2006 are documented in the paper Davies R., Horvath A, Moroney C., Zhang B., and Zhu Y. 2005. Cloud Motion Vectors from MISR Using Sub-pixel Enhancements. Remote Sensing of the Environment. Volume 107, Issues 1-2, pp 194-199.

A study of the MISR-retrieved winds against GOES data is published in the vol. 28, 2001 issue of Geophysical Research Letters (GRL). Height Comparisons made with MODIS, radar, and computationally intensive stereo matching algorithms are documented in the July 2002 issue of IEEE-TGARS and in the August 2002 issue of GRL. An additional study of the MISR heights and winds is available in the proceedings of the EUMETSAT Users' Conference (Antalya, October 2001) by G. Seiz.

Garay M.J., Mazzoni D., Davies R., and Diner D.J. 2005. The application of support vector machines to analysis of global satellite datasets from MISR. Proceedings of the Fourth Conference on Artifical Intelligence, American Meteorological Society, San Diego, CA 9-13 January 2005.

Horvath A., Davies R., Simultaneous retrieval of cloud motion and height from polar orbiter multi-angle measurements. GRL Vol 28, No. 15. 2915-2918 August 2001.

Moroney C., Davies R., Muller JP, 2002: Operational Retrieval of cloud-top heights using MISR data. IEEE Transactions on geoscience and remote sensing. 40 (7). 1532-1540 JUL 2002.

Marchand R., Ackerman T 2004: An assessment of Multi-angle Imaging Spectroradiometer (MISR) stereo-derived cloud top heights using ground-based millimeter-wavelength cloud radars. 14th International Conference on Clouds and Precipitation. Bologna Italy 19-23 July 2004.

Seiz, G., 2003. Ground and satellite-based multi-view determination of 3D cloud geometry. PhD thesis, Institute of Geodesy and Photogrammetry, ETH Zuerich, Switzerland, 2003. IGP Mitteilungen Nr. 80.

FILE FORMAT UPDATES

The TC_STEREO product underwent extensive revision in November 2002 (version F05_0008 of the product file): most of the 1.1 km and 2.2 km resolution field names have been changed, and they have also been re-ordered to put the most important fields at the top of each grid. Please see the Data Products Specifications documents for full details.

EXTERNAL DATA SOURCES

No external data sources such as the MODIS cloud-heights and the DAO/NSIDC snow-ice masks are used in the L2TC Processing. The snow-ice data are instead provided by monthly, static climatological inputs from the TASC Dataset.

ALGORITHM UPDATES

There have been several updates to the algorithms described in the ATBD. First, all the wind-retrieval disparities are slotted into a 2-d histogram and a weighted average around the most-populated value is used to calculate a single estimate of the wind for the domain. Secondly, the winds are now calculated separately for the fwd and aft camera triplets and are only accepted if the fwd-aft wind difference is small enough. If there is no stereoscopically retrieved height available, the StereoHeight and SDCM are set to NoRetrieval except in the case of clear-sky over ocean (as determined by the value of the Radiometric Camera-by-Camera Cloud Mask - RCCM) where the surface height is substituted for the missing stereo height. The RLRA is set to NoRetrieval where there is no stereo height, rather than being filled in with default values.

L2TC Classifiers (a.k.a. TC_CLASSIFIERS) (from MISR PGE8b)

The ASCM is Stage 2 Validated for all products with a version number of F05_0010 or greater. Sea-ice and snow cover over land are included in these statements. This version of the software went into production on June 01, 2007. The SVM Scene classifiers are debuting at Provisional level, while the SVM Cirrus Fraction is Beta quality. The consensus cloud classifiers are at Stage 2 Validated quality level following a few algorithm improvements and validation of their parent cloud masks.

The overall scene classifiers as computed from the SDCM, PreliminarySDCM, and RCCM are now Stage 2 Validated following the declaration of their parent products as Validated. The RCCM-based angle-by-angle cloud-fractions are Stage 3 Validated. Similarly, the SDCM-based and ASCM-based classifiers are Stage 2 Validated. The altitude-based scene classifiers are all Stage 2 Validated. The Classifiers version which has all the scene classifiers at Stage 2 and 3 Validated status is F06_0011. This version went into production on December 01, 2007. All Classifiers data at or above this version have all products at at least Stage 2 Validated status (with the exception of the SVM classifiers.

DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The differences in the SnowIce masks between successive years will affect the ASCM the most strongly, the RCCM differences will also show up in the TC_CLASSIFIERS product to a smaller extent.

The ASCM Thresholds have been revised to include separate snow-ice thresholds for these scene types, and the decision to use the regular or snow-ice thresholds is made by looking at the TASC. The differences will be most pronounced in those areas for which the snow or ice presence for that month is rather variable. Since the TASC has relatively coarse resolution (both spatially and temporally), the distinction between snow-ice and non snow-ice scenes will not be perfect, even in the FINAL processing. The few tests that have been done so far suggest a difference rate of about 2% of the pixels when calculated over an entire swath, and up to 40% in blocks where the snow-ice mask is very different between the two years. If the TASC indicates snow when there really isn't any, fewer clouds will be detected and some thin clouds will be labelled as clear. In the reverse case of the TASC dataset missing snow/ice that is actually present, the ASCM may call clear snow/ice cloudy by mistake.

REFERENCES

The physical basis of the ASCM algorithm is available in "A band- differenced angular signature technique for cirrus cloud detection", Di Girolamo L., and R. Davies, IEEE Trans. GeoSci. Remote Sens., vol 32, 1994. Note that although the ASCM is referred to as a cirrus cloud mask in this paper, it is being used as a general cloud mask.

CLOUD AND TOPOGRAPHIC SHADOW MASKS NOT AVAILABLE

The cloud and topographic shadow masks are currently not part of the Classifiers product. The lack of the cloud shadow mask can sometimes cause problems for the "Final" StereoHeights and SDCM as explained earlier in this document under SDCM validation.

ANGULAR SIGNATURE CLOUD MASK

The Angular Signature Cloud Mask (ASCM) is calculated by thresholding a single observable, namely the Band-Differenced Angular Signature (BDAS). The thresholds for the ASCM depend on the sun-view geometry, the underlying surface type, and season. The ASCM ocean and land thresholds have been updated and now contain seasonally dependant values. When the current validation is complete, this statement will be updated to present the results.

The ASCM is now calculated for all sun-view geometries, so the dead band over the equatorial regions in previous versions of the product has been removed. The ASCM now has complete coverage, as of version F05_0009.

Global cloud distribution maps made from the ASCM show the expected climatological cloud distributions. Validation via visual inspection, field campaigns and satellite data show that the ASCM has accuracies of better than 90% for ice-free ocean and greater than 85% for other surfaces including snow and ice cover. A detailed validation is underway and the results will be reported in this statement when available.

The visual discontinuities present in previous versions of the ASCM have been removed. The final ASCM is now calculated from the individual terrain-referenced versions masks for the forward and aft viewing camera pairs. This means that the ASCM is now terrain-referenced and is on a different projection from the SDCM. Therefore, doing high-resolution pixel-by-pixel comparisons of the three cloud masks is not recommended unless one fully understands the data and the projection issues.

CONSENSUS CLOUD CLASSIFIERS

A new cloud classifier that takes all three individual cloud masks (RCCM, SDCM and ASCM) into account has been added to the Classifiers product as of November 2004 (version F04_0005). These masks are available at 2.2km and 35.2km resolution and classify scenes into three types: "KnownClear" signifying that no cloud at all was detected in the pixel, "KnownCloud" meaning that some cloud was detected, and "Overcast" meaning that that the scene is entirely clouded over. Additionally the maximum stereo height is computed for all regions classified as Overcast. These data have not been formally validated yet and are therefore suitable only for informal use; their quality is Provisional. The coarse classifiers have been improved as of version F05_0009, but both the fine and coarse classifiers are still only meant to be used for rough scene classification.

SUPPORT VECTOR MACHINE SCENE CLASSIFIERS

The SVM scene classifier is being introduced at Provisional level following an extensive statistical (10 million pixels from 4 orbits) and visual (hundreds of scenes) validation. The principal classifier is divided into 5 possible classifications (Clouds, Aerosols, Ice/Snow, Water and Land) with two sub-classifications (Dust and Smoke) that are only relevant when the main classification is Aerosols. If the overall classification is not Aerosol, the Dust and Smoke fields should be ignored. The resolution is 1.1 km.

The overall accuracy of the 5-type classifier was found to be 80.9% compared to human expert labelling. When the results were resampled to a 17.6km resolution, the accuracy increases to 84.9%, indicating that a good portion of the errors are isolated blunders rather than gross misclassifications. On selected scenes, the agreement between two human experts doing the labelling was 93.0% at 1.1 km resolution and 96.3% at 17.6km resolution. These numbers therefore represent an estimate of the maximum performance possible for any scene classifier.

Since the SVM scene classifier makes its decision on the scene type using only the locally available data and does not use any information obtained from either the surrounding area or a priori knowledge, some strange classifications are possible. For example, some pixels in the middle of a large cloud will be labelled as ice/snow. Therefore, users of this data should consider the individual pixel results in the broader context of the overall scene.

The SVM has been tuned to detect as many aerosols as possible since they appear quite infrequently (about 1% of the data), thus leading to many false positives. If aerosols are present, the SVM will detect them about 75% of the time. However, for any given pixel that is labelled as aerosol, there is only a 33% chance that it is actually aerosol. Thin clouds are often mis-classified as aerosols. One will occasionally see a river being classified as aerosols while the surrounding land is labelled clear. This is expected behaviour: the variance in colour and texture is much lower for clear water than for land so the SVM is therefore sensitive to much thinner aerosols over water.

Ice and snow detection also cause particular problems since they also occur relatively infrequently. A pixel that is really covered with ice or snow has a 75% chance of being correctly labelled, but the probability that any given pixel with this label is actually ice or snow is only 54%.

The more popular classes of cloud, water and land all have accuracy rates in excess of 80%, both in terms of missing actual occurences of these surface types, and the rate of false positives. Sunglint does not cause a problem since the SVM classifier uses multiple angles in its calculations and the sunglint is typically limited to one or two angles at a time.

SUPPORT VECTOR MACHINE THIN CIRRUS DETECTION

The SVM cirrus detector is debuting at Beta since it has only been tuned for clear oceanic scenes. It is deliberately masked out over land. Cirrus retrievals are rare over any other scene type and any positive retrievals over these scenes should not be trusted. The results look visually reasonable over clear ocean but no quantitative validation has been done. Preliminary analysis with comparisons to ground-based lidar suggests cirrus with optical depths greater than 0.1 are detected using this technique.

The cirrus clouds are detected at 1.1km resolution using MISR's "C" cameras (60 degree tilting angle) and then reprojected to the An camera at 17.6km pixel resolution using climatological estimates of the cirrus height. It has not been determined how much error is due to deviations of the actual cloud height from the climatological estimates, however an error of 5km in the climatological cirrus height is required to cause the 1.1km pixel in the C camera to be reprojected to the incorrect 17.6km region in the An camera. Given that this is generally half the height of the tropopause, the use of the climatological cirrus heights is not expected to introduce a significant error.

CLOUD CLASSIFIERS FIELDS

Since the algorithm for determining the cloud classifiers is so simple, the quality of these products is directly derived from the incoming data. Therefore, one is urged to pay close attention to the quality statements for the SDCM, RCCM and ASCM. All the classifiers except the altitude-binned ones have the same quality as their parent cloud masks. The "BestWinds" version of the Stereo Heights and related cloud masks are used in the calculations of all these products.

The normalization error in the cloud fractions that was previously reported in this page has been fixed as of version F05_0009. Now the cloud fractions are correctly calculated by dividing by the number of pixels containing actual data, rather than by a constant value. So, the cloud fractions no longer uniformly decrease in value at the swath edges.

The altitude-binned classifiers remain at Stage 2 Validated because no systematic study has been done to determine how much low cloud is being missed because of the SDCM's inability to properly detect clouds lower than the height resolution, etc. One has to take the limitations of the stereo-height retrievals into account when looking at these classifiers.

The earlier problem with the An-camera RCCM as referenced to the cloud-top heights (FR_RCCM in the Stereo product) being masked out in sunglint areas has been corrected in version F07_0011 of the stereo product. This field and the "Combined Cloud Fractions" and "RCCM_AnByHeight" data are now completely populated.

FILE FORMAT CHANGES

The TC_CLASSIFIERS product has undergone extensive revision: most of the field names have been changed, and they have also been re-ordered to put the most important fields at the top of each grid. Please see the Data Products Specifications documents for full details.

L2TC Albedo (a.k.a. TC_ALBEDO) (from MISR PGE8c)

The Top-of-Atmosphere BRFs (and all accompanying parameters such as the top and side BRFs and the number of unobscured pixels), and all three texture indices are Stage 3 Validated. The Local, Restrictive and Expansive Albedos are Stage 1 Validated, along with their

Broadband equivalents.

The local albedos are internally consistent regardless of the modelling method used and compare well with the BRF images, and the restrictive and expansive albedos also pass visual inspection.

The accuracy of the albedos is limited by two factors - radiometric calibration and bidirectional corrections. All information in the Calibration Quality statement applies equally well to the albedos. At high latitudes, notably poleward of 60 degrees, the angular models currently fail due to extreme anistropy. Albedos in these regions are frequently over-estimated.

NEW ALBEDO ALGORITHMS USING CERES ADMs

The algorithms used to compute the clear-sky albedos have been drastically updated to use the CERES Angular Distribution Models, rather than relying on purely solid-angle weighting as in the past. The CERES data is used as of version F05_0009 of the product that went into operation June 2007. Now all of the local albedo calculations clear-sky use the CERES ADMs and these results trickle down to the Restrictive and Expansive albedos as well. Additionally, the Broadband Local Albedo has been added to the product file.

ERRORS CORRECTED IN LOCAL, RESTRICTIVE AND EXPANSIVE BROADBAND ALBEDOS

The errors described below have been **CORRECTED** in Version F05_0011 of the TC_ALBEDO products. The paragraph below is retained for anybody who may be forced to use older versions of the products, but since the entire mission is being reprocessed with version F05_0011, any use of these older products should of limited duration.

The new albedos that use the CERES ADMs have yet to be carefully validated, but already a mistake has been found in the software that calculates the broadband albedos. An incorrect formula has been used, which results in notable banding for $40.0 <=$ SolarZenithAngle < 50.0 (degrees) and incorrect broadband albedos throughout. In areas that not visibly banded, the expansive broadband albedos are usually too high by 0.1, and the restrictive and local albedos are affected by a smaller degree. Note that **none** of the Broadband albedo values are actually correct and they should not be used for scientific purposes.

DIFFERENCES BETWEEN FIRSTLOOK AND FINAL PROCESSING

The albedos are now influenced by the changes in the SnowIce mask from the TASC dataset, so there will be differences between the FIRSTLOOK and FINAL processing. The new algorithms use the CERES angular distribution models to calculate the local albedo, and the co-efficients are different between water, land, and snow-ice. Additionally they vary based on whether the snow-ice type is permanent snow, fresh snow or sea-ice.

Preliminary tests indicate that up to 5% of the Local Albedos (both narrowband and broadband) values may be different between the FIRSTLOOK and FINAL processing and these differences can be large in isolated cases. Similarly, about 5% of the Restrictive Albedos may be different between the two runs, and the difference rate for the Expansive Albedo could be 7 to 10%. The average differences for all these products are small, but there will always be outliers.

There is no detectable bias difference between the expansive and restrictive albedos. Regionally, their rms difference is approximately 0.04 to 0.10 depending on solar zenith angle. Based on limited studies to date, the rms uncertainty due to bidirectional modeling ranges from less than 0.01 at low latitudes to 0.03 at high latitudes (cloudy scenes only).

(OCCASIONAL) KNOWN PROBLEMS WITH RESTRICTIVE AND EXPANSIVE ALBEDOS

In about 50% of the orbits, the last two blocks of the ExpansiveAlbedoBroadband are filled with garbage data. The spectral equivalents are not affected. Since the last two blocks of the swath are over snow and ice, these albedos should be treated with caution anyways.

Occasionally, there will be NaN's in the Restrictive Albedos. This is usually limited to 1 or 2 pixels per swath, in about 30% of the orbits.

CALIBRATION

The reader is urged to pay close attention to the quality of the radiometric calibration as there have been some recent changes made. See the [Radiometric Calibration](#) section of the Level 1 Quality Statements.

FACTORS AFFECTING ALBEDO INTERPRETATION

The local albedo is defined as the unobscured reflection from the 2.2 km RLRA and will therefore often appear to be lower than would be expected. If the local albedos are not summarized statistically but instead are looked at on an individual basis, only the ones that have no obscuration should be used. (This information is available at 2.2 km resolution in the NumUnobscuredTop field. Any number >= 64 indicates that there was no obscuration).

Small fluctuations in the value of the RLRA will directly affect the obscuration and the local albedo. For continuous scenes, a 500 m RLRA difference (due to pixel quantization and other factors) typically results in up to a 10% difference in the local albedo due to obscuration effects. This effect is generally not as noticeable in scenes with naturally discontinuous height fields.

FILE FORMAT CHANGES

The TC_ALBEDO product underwent extensive revision in November 2002, (version F02_0004 of the product file): most of the field names

have been changed, and they have also been re-ordered to put the most important fields at the top of each grid. Please see the [Data Products Specifications documents](#) for full details.

LOCAL ALBEDO MODELLING ALGORITHMS

The Local Albedo calculation is first attempted by Deterministic Modelling (if the scene is homogenous), then Stochastic Modelling and finally solid-angle weighting. No modelling is attempted for clear-sky pixels or where the solar zenith angle is < 25.8 degrees. The weights used in the stochastic modelling are based on pre-launch theoretical simulations and will be updated in 2005 to reflect real measurements.

ALGORITHM UPDATES FROM ATBD REV. D

The algorithm for reprojecting the RLRA field down to the surface ellipsoid was found to be flawed and has been completely replaced with a new backwards-projection algorithm that reprojects the BRF's up to the RLRA.

Also see the:

- [Statement dated September 19, 2007](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from June 17, 2007 to September 19, 2007.
- [Statement dated August 22, 2006](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from August 21, 2006, to June 17, 2007.
- [Statement dated February 21, 2006](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from February 21, 2006, to August 21, 2006.
- [Statement dated December 1, 2005](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from December 1, 2005, to February 20, 2006.
- [Statement dated May 13, 2005](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from May 13, 2005, to November 30, 2005.
- [Statement dated November 28, 2004](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from November 28, 2004, 2004 to May 12, 2005.
- [Statement dated February 13, 2004](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from November 30, 2003 to November 27, 2004.
- [Statement dated October 20, 2003](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from October 20, 2003 to November 30, 2003.
- [Statement dated August 13, 2003](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from August 13, 2003 to October 19, 2003.
- [Statement dated November 12, 2002](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from November 12, 2002 to August 12, 2003.
- [Statement dated April 15, 2002](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from April 15 to November 11, 2002.
- [Statement dated December 03, 2001](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from December 03 to April 14, 2002.
- [Statement dated September 27, 2001](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from September 27 to December 03, 2001.
- [Statement dated March 30, 2001](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from March 30 to September 27, 2001.
- [Statement dated February 16, 2001](#) for MISR Level 2 Top-of-Atmosphere/Cloud Products from February 16 to March 30, 2001.