# MISR Level 2 Cloud Product Quality Statement
# September 14, 2012

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## Quality Designator:

- **Stage 3 Validated:** Cloud Top Heights (Without Wind Correction)[1]
- **Stage 1 Validated:** Cloud Motion Vectors, Cloud Top Heights[1], Stereo Derived Cloud Mask
- **Provisional:** Cross-track Cloud Motion Components

[1]Two versions of cloud top heights are provided. Those simply named "Cloud Top Height" include a correction for cloud motion, while those labeled "Without Wind Correction" do not. See the DPS and ATBD for additional information.

MISR maturity level definitions

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### INTRODUCTION

This statement applies to parameters included in the MISR Level 2 Cloud (TC_CLOUD) product (versions F01_0001 and greater). Quality statements covering earlier time periods may be accessed through links at the bottom of this page.

Readers are also advised to consult the Data Product Specifications (PDF), and Algorithm Theoretical Basis Document (ATBD).

This statement references both internal and published evaluations of accuracy and coverage for TC_CLOUD cloud motion vectors (provided at 17.6 km resolution, including associated cloud top height), cloud top heights (provided at 1.1 km resolution), and cross-track cloud motion components (provided at 1.1 km resolution). Note that *along-track* refers to motion in the direction of the satellite orbit (close to south except at high latitude) and *cross-track* refers to relatively orthogonal motion (close to east except at high latitudes).

### CLOUD MOTION VECTORS

TC_CLOUD provides cloud motion vectors (including associated cloud top heights) at 17.6 km resolution with Stage 1 validation status.

TC_CLOUD provides a cloud motion vector for 70 percent of cloudy areas over ocean and cloudy or clear areas over land observed by MISR. This was calculated from January and July 2007 data by reviewing the fraction of 1.1 km resolution pixels observed by MISR for which both a 1.1 km resolution cloud top height and a collocated 17.6 km cloud motion vector of similar height are present. Pixels over ocean designated by the MISR Radiometric Camera-by-camera Cloud Mask (RCCM) product as cloud-free were excluded.

TC_CLOUD cloud motion vectors have been compared with collocated Geostationary Operational Environmental Satellite (GOES), Meteosat-9, MODIS (aboard Terra), and radiosonde (RAOB) atmospheric motion vectors (AMV). In most comparions, MISR cloud top heights (CTH) have been used to divide the analysis into low (CTH < 3 km), middle (3 km < CTH < 7 km), and high (CTH > 7 km) clouds.

**MISR vs. GOES AMV Intercomparison, Jan./Jul. 2007**

| Statistic | MISR height bin | | |
|---|---|---|---|
| | 0-3 km | 3-7 km | 7+ km |
| Collocations | 52600 | 3700 | 8500 |
| Component bias (along, cross-track) | (0.1, -0.3) m/s | (1.4, 0.0) m/s | (1.8, -0.2) m/s |
| Component RMS (along, cross-track) | (2.7, 1.8) m/s | (5.1, 3.5) m/s | (5.7, 3.5) m/s |
| Vector RMSE | 3.3 m/s | 6.3 m/s | 6.8 m/s |

**MISR vs. Meteosat-9 AMV Intercomparison, 2008**

| | |
|---|---|
| Collocations | 225155 |
| Component bias (north, east) | (-0.0, -0.3) m/s |

| | |
|---|---|
| Component RMS (north, east) | (3.1, 2.8) m/s |
| Height bias | 190 m |
| Height RMS | 1220 m |
| *Results courtesy of Akos Horvath, Leibniz Institute for Tropospheric Research* | |

**MISR vs. arctic MODIS AMV Intercomparison, Jan./Jul. 2007**

| Statistic | MISR height bin | | |
|---|---|---|---|
| | **0-3 km** | **3-7 km** | **7+ km** |
| Collocations | 8740 | 13490 | 1030 |
| Component bias (along, cross-track) | (1.5, -0.4) m/s | (1.3, -0.1) m/s | (3.5, 0.2) m/s |
| Component RMS (along, cross-track) | (4.3, 3.7) m/s | (4.1, 3.2) m/s | (6.7, 4.7) m/s |
| Vector RMSE | 5.9 m/s | 5.4 m/s | 8.9 m/s |

**MISR vs. arctic RAOB AMV Intercomparison, 2002-2008**

| Statistic | MISR height bin | | |
|---|---|---|---|
| | **0-3 km** | **3-7 km** | **7+ km** |
| Collocations | 206 | 67 | 19 |
| Component bias (along, cross-track) | (0.6, 0.0) m/s | (1.3, 0.0) m/s | (0.3, 0.5) m/s |
| Component RMS (along, cross-track) | (4.7, 3.5) m/s | (4.1, 3.2) m/s | (3.8, 1.9) m/s |
| Vector RMSE | 5.9 m/s | 5.3 m/s | 4.3 m/s |

## CLOUD TOP HEIGHTS

TC_CLOUD provides two 1.1 km resolution height parameters, *CloudTopHeight* and *CloudTopHeight_WithoutWindCorrection*, whose respective validation statuses are Stage 1 and Stage 3. The *CloudTopHeight_WithoutWindCorrection* has a greater validation status because the performance of the underlying algorithm has been well documented through studies of the TC_STEREO product [e.g., Garay et al., 2008; Marchand et al. 2007; Moroney et al. 2002; Naud et al. 2007; Naud et al. 2005], while the *CloudTopHeight* parameter has not been as thoroughly validated against external data sources.

Though similar to TC_STEREO, TC_CLOUD heights do feature three noteworthy improvements: (1) image contrast requirements for attempting retrieval have been relaxed, resulting in greater coverage; (2) quality control procedures are more strict, reducing noise; and (3) reported heights are now an average, rather than a maximum, of estimates obtained from different cameras, improving accuracy. Due to the last improvement, TC_CLOUD heights were found to be lower than TC_STEREO heights by an average of 200 m in a comparison of the two datasets made for the year 2007

TC_CLOUD provides cloud top heights for 70 percent of cloudy areas over ocean and cloudy or clear areas over terrain observed by MISR and provides cloud top heights without wind correction for 80 percent of these areas. These percentages were calculated from January and July 2007 data by reviewing the fraction of observed pixels with associated cloud top heights, while excluding pixels over ocean designated by the MISR RCCM as cloud-free. Cloud top height retrieval may be unssuccessful for many reasons, including insufficient cloud optical depth. Marchand et al. [2007] report that the minimum cloud optical depth for successful MISR stereo height retrieval ranges from 0.3 to 0.5 depending on the underlying surface.

TC_STEREO cloud top heights were found by Marchand et al. [2007] to have a standard deviation of error of less than 1000 m relative to ground-based radar estimates at three sites of the Atmospheric Radiation Measurement (ARM) program sites.

## CROSS-TRACK CLOUD MOTION COMPONENTS

TC_CLOUD cross-track cloud motion components identified by the cloud mask as associated with terrain features were found to exhibit a mean bias of 0.3 m/s with a standard deviation of error of 3.8 m/s relative to the expected value of 0 m/s based on examination of data from July of 2007. Note that retrieval accuracy may be different for cloud features than for terrain features.

## PRACTICAL LIMITATIONS

Here we present specific practical limitations associated with TC_CLOUD algorithms and data. Underlying theoretical limitations are discussed in the Algorithm Theoretical Basis Document (PDF).

TC_CLOUD cloud motion vectors, cloud top heights, and cross-track cloud motion components do not exclusively contain values representing meteorological clouds. The underlying retrieval mechanism operates on identifiable features within MISR camera images that may be associated with cloud, aerosol, or terrain, and may also be spurious. Cloud masks are provided for limiting sampling to only clouds. For meteorological clouds, the heights of features can feasibly represent the interior rather than the top of the cloud because clouds do not have an opaque outer surface.

TC_CLOUD algorithms are optimized to retrieve cloud motion vectors with heights between 0 and 20 km, and speeds up to 50 m/s. The current retrieval method does generate some heights and speeds outside this range which are included in the product. Some of these heights and speeds are obviously unrealistic. Our analysis finds typical percentages of unrealistic values among reported motion vectors in the ranges per orbit of ~0.02% in the mid-latitudes to ~0.10% at the poles. Of these, some 80% are assigned Quality Indicator (QI) values less than 50, indicating low confidence in the retrieval. Methods for additional flagging of these parameters are under investigation for inclusion in the next reprocessing cycle.

Cloud motion vector accuracy is sensitive to the georegistration accuracy of the MISR L1B2 input. This sensitivity is estimated to range from 6 m/s/pixel to 16 m/s/pixel depending on the camera view angle [Davies et al., 2007; Zong et al., 2002]. Georegistration accuracy can vary significantly by camera and is notably a function of the quantity of terrain observed by MISR during a particular orbit. A small fraction of orbits (e.g., 7% in data from 2007) are identified by quality control procedures as having insufficient georegistration accuracy for cloud motion vector retrieval. Such orbits are flagged as poorly registered and provide only cloud top heights without wind correction.

Cloud motion vectors are subject to bias related to L1B2 georegistration that is weakly correlated with cross-track position within the MISR swath. The northward and eastward components of this bias are constrained within ± 1 m/s over the range of positions across the swath, as is shown in the Figure 1 comparison between TC_CLOUD and Meteosat-9 motion vectors.

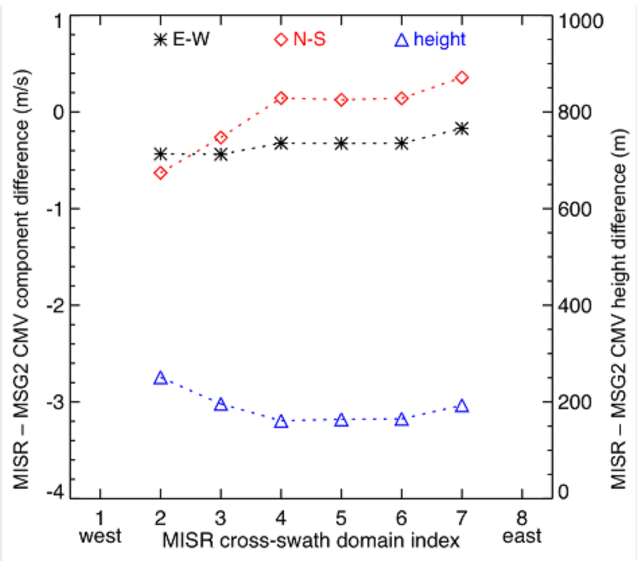


**Figure 1**: Differences in height, northward motion (N-S), and eastward motion (E-W) of MISR TC_CLOUD cloud motion vectors (CMV) relative to collocated Meteosat-9 (MSG2) CMV as a function of cross-swath domain index ranging from the 70.4 km interval at the far western edge of a MISR block (index 1) to the interval at the far eastern edge (index 8). For the analysis shown, TC_CLOUD CMV have been averaged from 17.6 km resolution to 70.4 km resolution. Data are from 2008. Methodology is detailed by Lonitz and Horvath, 2011. Figure courtesy of Akos Horvath, Leibniz Institute for Tropospheric Research.

Unlike the atmospheric motion vectors derived from comparable passive sensors, TC_CLOUD cloud motion vectors are not obtained independently from their associated cloud top heights. Notably, error in the height of a cloud motion vector is not independent of error in the along-track component of motion [Zong et al., 2002].

The dominant source of cloud top height error is the bias correction (or lack thereof) for along-track cloud motion. Cloud top heights have a nominal bias of -90 m per 1 m/s of bias in the along-track motion component used for correction. The along track motion is assumed to be zero for cloud top heights without wind correction.

Visualizations of cloud top heights occasionally exhibit sampling artifacts or discontinuities in retrieval values along the edges of the MISR observational swath. Such discontinuities align with the boundaries of L1B2 georegistration transform domains that occur every half block of data. These effects are the expected result of less accurate L1B2 georegistration along swath edges and do not reflect reduced accuracy in reported heights.

Cross-track cloud motion components are only provided within a predefined, nominally 280 km wide interior of the MISR observational swath to avoid any issues that may arise from their greater sensitivity to L1B2 registration accuracy along the swath edges.

Cloud top heights and cross-track cloud motion components are initially computed on the basis of discrete pixel intervals, ultimately yielding cloud top height values discretized at a nominal interval of 560 m for heights and 6.1 m/s for cross-track motion. In many circumstances, discretization error will be mitigated by the fact that the final value reported to the users is an average of discretized estimates produced from distinct pairs of MISR cameras.

## REFERENCES


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Also see the

- Statement dated February 21, 2012.