MISR Level 3 Cloud Fraction by
Altitude Product Quality Statement
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Quality Designator:

- Stage 2 Validated: Global Cloud Fraction by Altitude Product

MISR maturity level definitions

This statement applies to the MISR Level 3 Cloud Fraction by Altitude product (Versions F01_0002 and F01_0003) and beyond until further improvements to the MISR software or ancillary inputs are made. See the Versioning page for an in-depth explanation of the differences between various MISR product versions. Quality statements covering earlier time periods may be accessed through at the bottom of this page.

The evaluation of product quality is ongoing. Please read the summary words of caution {I was not able to find this link} if you have not done so already.

The MISR Level 3 CFbA software that generated these products is believed to be functioning well except where noted below. This statement describes the quality and uncertainty of product, guidance in its scientific use, and changes from the previous versions.

OVERVIEW

The CFbA product provides the frequency of cloud occurrence partitioned into different cloud-top altitude bins at a global and monthly scale with a spatial resolution 0.5° x 0.5° latitude/longitude and vertical resolution of 500m. The vertical integration of these frequencies leads to the total cloud fraction, which is also reported in the CFbA product. Complete CFbA algorithm details can be found in the Level 3 Cloud Fraction by Altitude Algorithm Theoretical Basis Document.

PROBLEM WITH CFbA FROM JUNE 2014 TO MAY 2017 for version F01_0002

An error in the Snow Ice Mask was discovered which affects the quality of the CFbA between June 2014 and May 2017. See the Level 2 Cloud Classifiers Quality Statement for details. Briefly, this error results in lowered cloud fractions primarily over the Canadian Arctic in the (lat, long) range of (81 N, 110 W) to (73 N, 80 W). The CFbA for this three-year period has been regenerated and assigned a version number of F01_0003. For all products outside this time range, the F01_0002 CFbA are current and not impacted by this error.

UNCERTAINTY, QUALITY AND KNOWN LIMITATIONS

The RCCM (contained in the GRP_RCCM product), SDCM (from TC_CLOUD) and ASCM (TC_CLASSIFIERS) are used to calculate cloud fractions used in the CFbA. Additionally, the cloud-top heights are calculated in the TC_CLASSIFIERS product using input from TC_CLOUD. Therefore the information contained in the GRP_RCCM, TC_CLOUD and TC_CLASSIFIERS quality statements is of value when using this product.

Keep the following in mind when using the CFbA product in scientific analyses:

1. The heights are calculated by a stereoscopic method and therefore retrieve the altitude of greatest spatial contrast as viewed by multiple MISR cameras. This may differ from the heights retrieved by a LIDAR or an IR sensor. The cloud optical depth threshold at which the stereo algorithm identifies thin clouds depends, in part, on the contrast of the underlying surface. Therefore, MISR can detect thinner single-layered clouds over ocean than compared to land. Where heights are retrieved, RMS errors have been determined to be ~ 560 m (see Level 2 cloud quality statement).

2. Only the heights that are deemed to be cloud (as determined by the SDCM) are reported in this product. Since the SDCM is calculated by comparing the retrieved height against that of the sum of the (a) terrain height, (b) standard deviation of the terrain heights and (c) a constant 562m, and its algorithm calls any heights less than this sum "Clear or Near Surface", it is rare to see any entries in the 0-500 m height bin. Indeed, this can only happen when surface altitudes are significantly below the WGS84 surface ellipsoid. The northern Indian ocean is a large area where the sea surface is nearly 100 m below the surface ellipsoid. Hence, it is one of the few places where clouds can be found in the 0 - 500m altitude bin

3. When a thin high-altitude cloud layer is present over lower and thicker clouds, height retrieval algorithms will preferentially (and without loss of accuracy) retrieve the height of the cloud layer with greater spatial contrast, which is likely to be the lower cloud layer. Therefore, if comparing MISR cloud heights with those derived from conventional IR, MISR will report a smaller fraction of high cloud and larger fraction of low cloud, but the total cloud fraction remains comparable assuming the datasets have the same cloud detection sensitivities. A detailed comparison with other satellite datasets was conducted by the GEWEX Cloud Assesment Working Group.

4. MISR stereo does not report cloud heights for all pixels detected as cloud by the MISR cloud masks. For example, a cloud with limited spatial contrast may not have a height retrieval. To deal with the potential sampling artifact that may arise from these no-retrieved heights, an additional field is added to the product with designation "NN." These "NN" fields employ a nearest-neighbor search for heights that, combined with the MISR cloud masks, minimizes the sampling artifacts that may arise from cloudy pixels for which no height has been retrieved. Where the search is unsuccessful, the cloud fraction of pixels with no assigned height is incremented. This quantity is recorded in the CFbA product and accounted for in the total cloud fraction as reported in the product (see Algorithm Theoretical Basis document for details).

5. The total cloud fraction is the fraction of pixels detected as containing "some" cloud. Over snow- and ice-free regions, the MISR cloud mask effectively reveals sub-pixel clouds (see Level 2 cloud quality statements). Since sub-pixel clouds (by definition) do not fully cover a pixel, the true cloud fractions (as would be defined by a perfect cloud detector using pixels that are near infinitesimal in size) reported in the CFbA will be overestimated in regions populated by small clouds (e.g., trade wind cumulus regions). A full discussion on this issue is given in Zhao and Di Girolamo (2006). An algorithm to correct the overestimation of cloud fraction, based on Di Girolamo and Davies (1997), has been implemented in the TC_CLASSIFIERS product and its potential use in the CFbA will be investigated. Its impact on the cloud climatology over the tropical eastern Atlantic is shown in Jones et al. (2010), where cloud fractions in this trade wind cumulus cloud region were reduced by a factor of two after correcting for the bias caused by the finite resolution of the MISR instrument. In other parts of the world that are dominated by stratiform clouds, the finite resolution of the MISR instrument will have negligible impacts on cloud fraction.

6. Since land surfaces provide greater underlying spatial contrast compared to ocean, the MISR stereo and cloud detection algorithms will miss a greater fraction of visibly thin clouds over land. It has been determined that total cloud fraction over snow-free land and ice-free ocean is

biased low by ~7% and ~2%, respectively (see TC_CLOUD quality statement and Di Girolamo et al. (2014)). This is relative to supervised support vector machine classification on a large number of randomly selected scenes applied to the RCCM, which acts as the main input for cloud fraction for the CFbA over snow- and ice-free surfaces.

7. The CFbA algorithm uses different inputs depending on whether or not the underlying surface contains snow or ice. To do so requires a snow and ice mask. The snow and ice mask used by MISR is a monthly mask at 1-degree resolution. A 1-degree grid is labeled snow/ice if > 5% of the region has snow/ice for more than 4 days of the month based on NSIDC/NISE data. Where labeled snow/ice covered, snow/ice thresholds for the ASCM are used. When these thresholds are applied to 1.1-km pixels that are, in truth, not covered by snow/ice within the snow/ice-labeled 1-degree region, an underestimation of cloud occurs. The result is that the CFbA produces an underestimate in cloud fraction in polar regions, particularly near the snow/ice - snow/ice-free boundaries...

8. The CFbA product is derived from observations only captured during daylight. At lower latitudes, these observations will only occur during the descending node of the Terra satellite, which has a constant nominal equator-crossing time of 10:30 A.M local time. At high latitudes, a monthly grid-cell in the summer hemisphere will contain data sampled from both the ascending and descending nodes, representing two ranges of solar zenith angle and local time of observation. Any diurnal cycle in cloud cover that exists in the high-latitude summer hemisphere, or unknown solar zenith angle bias in cloud detection and cloud-height retrievals, gets folded into the mean values of cloud fraction by altitude reported in the CFbA.

9. Stereo processing requires high-quality image navigation of the orbit. Orbits that are deemed to be poorly registered (as determined by either the results of Level 1 or Level 2 analysis) are removed from processing. These poorly registered orbits are not evenly distributed as some orbits have fewer ground-control points than others. The number of ground-control points varies based on geographic path and time of year. As a result, not all longitudes along a given latitude line are sampled equally. We strongly recommend that users of the CFbA product consider the sampling information provided within the product.

10. Optically thick aerosols, such as from smoke and sand storms, may be misclassified as cloud by the MISR cloud masks, thus contributing to the cloud fraction. In regions of the world where these thick aerosols are prone to occur, the cloud fraction may be overestimated. The degree to which this occurs and its impact on the CFbA has not been ascertained, but the impact on the CFbA monthly product is expected to be small for most of the globe given the infrequent occurrence of thick aerosols over the course of a month for most locations on the globe.

CHANGES FROM PREVIOUS VERSIONS

Even though the CFbA algorithm itself has not changed, this version has significant differences from previous ones due to input changes upsteam. The CFbA uses the fields *CombinedFraction-CloudBestEstimate* and *MedianCloudHeight* from the TC_CLASSIFIERS product, and the current version of TC_CLASSIFIERS (F07_0012) now calculates those two fields using the TC_CLOUD as input, rather than TC_STEREO. See the TC_CLOUD quality statement for more details on the differences between it and TC_STEREO. In addition, the feature-referenced ASCM is now used to calculate the *CombinedFractionCloudBestEstimate*, rather than the terrain-referenced version in older versions of TC_CLASSIFIERS. The feature-referenced ASCM has decreased coverage at the swath edges, due to lack of An camera data.

1. In general, the fraction for the NoRetrieval height bin in the current CFbA product is significantly smaller than the previous versions, because of the improved height coverage in TC_CLOUD.

2. Cloud fractions in each height bin excluding NoRetrieval height bins in this version are generally larger than the previous version especially for the fields without NearestNeighbor approach because of an increase in the number of cloudy pixels sampled for each height bin.

3. The total cloud fraction over snow-ice covered regions is larger than in the previous version, primarily due to a significant increase in the SDCM coverage over these areas.

4. The CFbA also shows increased cloud-fraction in high level height bin over cirrus dominated regions, again due to increased sampling in TC_CLOUD compared to TC_STEREO.

5. Over snow-ice free regions, total cloud fraction differs because more orbits of data are included in the CFbA processing. A change in the orbital-quality-check algorithm in TC_CLOUD has reduced the number of orbits which are deemed too badly registered to permit accurate cloud-top-height retrievals in TC_STEREO.

6. The distribution of cloud fraction across all the height bins (excluding the NoRetrieval one) may shift towards lower height bins (approximately 200-300 m on average) over the regions where the same clouds are sampled as a result of an algorithm change in TC_CLOUD pertaining to the combination of the individual fwd/aft retrievals.

REFERENCES

Di Girolamo, L., and R. Davies, 1997: Cloud fraction errors caused by finite resolution measurements. *J. Geophys. Res.*, 102, 1739-1756.

Di Girolamo, L. et al., 2014: The Multi-angle Imaging SpectroRadiometer cloud masks: algorithm descriptions and performances. *J. Atmos. Ocean. Tech.* (in preparation).

Jones, A.L., L. Di Girolamo and G. Zhao, Reducing the resolution bias in cloud fraction from satellite derived clear-conservative cloud masks, *J. Geophys. Res.*, 117, D12201, doi:10.1029/2011JD017195

Zhao, G. and L. Di Girolamo, 2006: Cloud fraction errors for trade wind cumuli from EOS-Terra instruments. *Geophys. Res. Lett.*, 33, L20802, doi:10.1029/2006GL027088
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Also see the:

Statement dated September 09, 2017 for MISR Level 2 Top-of-Atmosphere/Cloud products from June 17, 2007 to September 19, 2007.