**MODIS Multi-Angle Implementation of Atmospheric Correct (MAIAC)**

**Data User’s Guide**

**Collection 6 (ver. of June 2017)**

**Version 2.0**

**Principal Investigator: Alexei Lyapustin**

Correspondence e-mail address:

[Yujie.Wang@nasa.gov](mailto:Yujie.Wang@nasa.gov); [Alexei.I.Lyapustin@nasa.gov](mailto:Alexei.I.Lyapustin@nasa.gov);

**Prepared by Alexei Lyapustin and Yujie Wang**

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# 1. Introduction

MAIAC is a new advanced algorithm which uses time series analysis and a combination of pixel- and image-based processing to improve accuracy of cloud detection, aerosol retrievals and atmospheric correction (*Lyapustin et al*., 2011a,b; 2012; publication on current MAIAC is under preparation). The underlying physical idea behind MAIAC is simple: because surface changes slowly in time compared to aerosols and clouds given the daily rate of global MODIS observations, we focus on extensive characterization of the surface background in order to improve all stages of MAIAC processing. MAIAC starts with gridding MODIS measurements (L1B data) to a fixed grid at 1km resolution in order to observe the same grid cell over time and work with polar-orbiting observations as if they were “geostationary”. In this regard, this approach is fundamentally different from the conventional swath-based processing where the footprint changes with orbit and view geometry (scan angle) making it difficult to characterize always changing surface background.

To enable the time series analysis, MAIAC implements the sliding window technique by storing from 4 (at poles) to 16 (at equator) days of past observations in operational memory. This helps us retrieve surface BRDF from accumulated multi-angle set of observations, and detect seasonal (slow) and rapid surface change. A detailed knowledge of the previous surface state also helps MAIAC’s internal dynamic land-water-snow classification including snow detection and characterization.

Consistently with the entire C6 MODIS land processing, the top-of-atmosphere (TOA) L1B reflectance includes standard C6 calibration (*Toller et al*., 2014) augmented with polarization correction for MODIS Terra (*Meister et al*., 2012), residual de-trending and MODIS Terra-to-Aqua cross-calibration (*Lyapustin et.al*, 2014). The L1B data are first gridded into 1km MODIS sinusoid grid using area-weighted method (*Wolf et al*., 1998). Due to cross-calibration, MAIAC processes MODIS Terra and Aqua jointly as a single sensor.

**2. Overview of MAIAC products**

MAIAC provides a suite of atmospheric and surface products in three HDF4 files: *daily* MAIAC[TA]BRF (spectral BRF, or surface reflectance), *daily* MAIAC[TA]AOT (atmospheric properties), and *8-day* MAIACRTLS (spectral BRDF/albedo).

**2.1 Tiled File Structure and Naming Convention**

Products are by default reported on 1km sinusoidal grid. The sinusoidal projection is not optimal due to distortions at high latitudes and off the grid-center, but it is a tradeoff made by the MODIS land team for the global data processing. The gridded data are divided into 1200x1200km2 standard MODIS tiles shown in Figure 1.

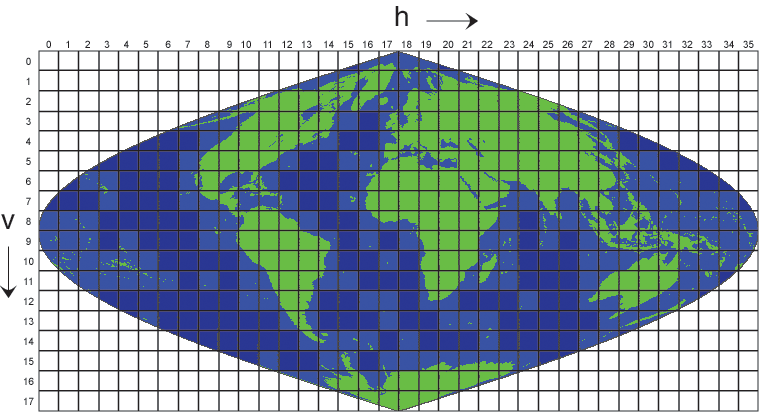
Users can also define their own projections to minimize map distortions by changing the run time parameters before the data is processed. We have currently predefined five local projections for users’ convenience: AlaskaCananda, Asia, Australia, NA (North America), SouthAmerica.

The current dataset presents data per orbit (we do not provide a daily composite image as in standard MODIS surface reflectance product MOD09). Each daily file name follows name convention below, for instance:

MAIAC[TA]AOT.TileNumber.TimeOfObservation.hdf

T stands for Terra and A stands for Aqua

TimeOfObservation has the format “YYYYDDDHHMM”, where YYYY is year, DDD is Julian day, HH is hour MM is minute.



**Figure 1. Illustration of MODIS Sinusoidal Tiles.**

**2.2 MAIAC Products: General Description**

In C6 Collection, MAIAC reports spectral BRF, BRDF, snow fraction, snow grain size, column water vapor, and aerosol optical depth (AOD) for both land and water. Over water, MAIAC also reports fine mode fraction, and spectral reflectance of underlight (or equivalent reflectance of water-leaving radiance).

**2.2.1 Atmospheric Properties File (MAIAC[TA]AOT)**

For each orbit, MAIACatmospheric properties file includes:

Over land:

* *column water vapor* (CWV) retrieved from MODIS near-IR bands B17-B19 at 0.94μm (in cm). CWV is reported for both clear and cloudy pixels. In the latter case, it represents water vapor above the cloud;
* *aerosol optical depth and type* (background, biomass burning or dust). The AOD is originally retrieved (and reported) in MODIS Blue band B3 (0.47μm). Because the common input for the chemical transport models and GCMs as well as AOD validation and AOD product intercomparison are standardized to 0.55μm, we also provide the “Green” band (B4) AOD. It is computed from 0.47μm based on spectral properties of regional aerosol model used in retrievals. Validation shows that quality of AOD at 0.55μm is generally close though slightly worse than the original retrieval at 0.47μm. Currently, AOD is not retrieved at high altitudes >3.5km, except when Smoke/Dust aerosol is detected. Rather, we report static “climatology” value of 0.01 which is used for atmospheric correction. Our study showed that in conditions of very low AOD, non-flat terrain and generally bright surface, MAIAC aerosol retrievals at high altitudes are unreliable.
* *AOD uncertainty:* This parameter is evaluated based on the Blue-band B3 surface brightness (reflectance) only, and thus gives only a general indication of possible increase of error over brighter surfaces;
* *Injection Height* of Smoke plume (in m above ground): Reported near detected fire hot spots when smoke plume is optically thick and exhibits brightness temperature contrast with the previous clear observation or with unobscured neighbor land surface. A limited validation against MISR MINX plume height for the case of Idaho-Wyoming fires of 2014 showed a reasonable accuracy within ~500m (publication in preparation). This product is experimental and requires thorough investigation.

Over water:

* *AOD* outside of glint area (glint angle ≥ 40°). When MAIAC detects dust, AOD is also reported for smaller glint angles if the retrieved value is above zero.
* *Fine Mode Fraction (FMF)* is reported along with AOD over open ocean and large in-land lakes (like Great Lakes of North America). It is not retrieved over small in-land water bodies.

View Geometry over land and water *at 5km*:

* *Cosines of Solar and View zenith angles, relative azimuth, scattering angle and glint angle*.

**2.2.2 Surface Reflectance File (MAIAC[TA]BRF)**

For each orbit, MAIAC *daily* surface reflectance file includes:

Over land (for solar zenith angles below 80°):

* *1km BRF (surface reflectance)* in MODIS land and unsaturated ocean bands B1-B12. It is produced in cloud-free and clear-to-moderately turbid (AOD0.47<1.5) conditions;
* *500m BRF,* nested in 1km grid,in MODIS land bands B1-B7;
* *1km BRF uncertainty (Sigma\_BRFn)* in MODIS Red (B1) and NIR (B2) bands. BRF uncertainty is required for higher level land algorithms, such as LAI/FPAR (*Chen, Knyazikhin et al.*, 2017), global model assimilation etc. We define it as a standard deviation of the geometrically normalized BRFn over 16-day period under assumption that surface is stable or changes linearly in time. As such, this is the most conservative estimate of uncertainty which includes contribution from gridding, undetected clouds, errors of atmospheric correction including those from aerosol retrievals, and of surface change when reflectance change is non-linear over time. As one can see, this definition of uncertainty is much broader than the one that may come from “theoretical” considerations, but it is also much more realistic. Sigma\_BRFn in the Red band can serve as a proxy of uncertainty at shorter wavelengths, where the surface is generally darker, and the NIR value can be a proxy for the longer wavelengths with high surface reflectance.

When snow is detected, we also compute snow grain size (diameter, in mm) which governs spectral snow albedo for pure snow, and sub-pixel snow fraction. The algorithm is based on a linear mixture model of spectral snow reflectance (*Lyapustin et al.*, 2010) and pure land spectral BRDF for every land grid cell. Processing uses minimization of MODIS reflectance in bands B1, B5, B7. The residual between the best fit and MODIS observations in B1,B5,B7 is reported in parameter Snow\_Fit:

* *Snow grain size* (diameter, in mm) at 1km;
* *Sub-pixel snow fraction* (range 0-1) at 1km;
* *Snow Fit* (rmse for the best fit and MODIS observations in B1,B5,B7) at 1km.

View Geometry and Kernels of RTLS BRDF model *at 5km*:

* *Cosines of Solar and View zenith angles, relative azimuth, Sun azimuth (SAZ), sensor view azimuth (VAZ), scattering angle and glint angle*.
* *Volumetric* (F0v) *and geometric-optics* (F0g) *kernels of RTLS model* for the observation geometry. Kernels are provided for geometric- (or BRDF-) normalization of spectral BRFs, which is needed in many tasks, such as change detection, geophysical and calibration trend analysis (e.g., *Lyapustin et al*., 2012; 2014) etc. Then, the BRDF (or geometry)-normalization can be done using spectral BRDF kernel weights {kL, kV, kG} from file MCD19A3 based on the following formula (see Eqs. (6) and (8) from *Lyapustin et al*., 2012):

BRFn = BRF \* (kL - 0.0458621\*kV - 1.1068192\*kG)/( kL + F0V\*kV + F0G\*kG).

This equation normalizes BRF from a given view geometry to the fixed geometry of nadir view and 45° sun zenith angle (FV(45)=-0.0458621, Fg(45)=-1.1068192). One can easily modify normalization to a preferable Sun angle according to latitude or season, by replacing coefficients in the numerator with values from the following table 1 built for different solar zenith angles and nadir view.

The 5km reporting scale for geometry and volumetric and geometric-optics kernels is sufficient as geometry changes slowly.

|  |  |  |
| --- | --- | --- |
| SZA | Fv(SZA) | Fg(SZA) |
| 0 | 0 | 0 |
| 1 | -0.0000589 | -0.0222231 |
| 2 | -0.0002322 | -0.0444532 |
| 3 | -0.0005146 | -0.0666974 |
| 4 | -0.000901 | -0.0889604 |
| 5 | -0.0013863 | -0.1112519 |
| 6 | -0.0019654 | -0.1335773 |
| 7 | -0.0026334 | -0.1559435 |
| 8 | -0.0033854 | -0.1783573 |
| 9 | -0.0042163 | -0.2008253 |
| 10 | -0.0051215 | -0.2233558 |
| 11 | -0.006096 | -0.2459545 |
| 12 | -0.0071349 | -0.2686286 |
| 13 | -0.0082336 | -0.2913864 |
| 14 | -0.0093873 | -0.3142342 |
| 15 | -0.0105912 | -0.3371795 |
| 16 | -0.0118406 | -0.3602294 |
| 17 | -0.0131308 | -0.3833919 |
| 18 | -0.0144569 | -0.4066738 |
| 19 | -0.0158144 | -0.4300835 |
| 20 | -0.0171985 | -0.4536282 |
| 21 | -0.0186043 | -0.4773155 |
| 22 | -0.0200272 | -0.5011534 |
| 23 | -0.0214623 | -0.5251498 |
| 24 | -0.0229049 | -0.5493125 |
| 25 | -0.0243501 | -0.5736493 |
| 26 | -0.025793 | -0.5981684 |
| 27 | -0.0272287 | -0.6228774 |
| 28 | -0.0286523 | -0.6477844 |
| 29 | -0.0300587 | -0.6728968 |
| 30 | -0.0314429 | -0.6982225 |
| 31 | -0.0327997 | -0.7237687 |
| 32 | -0.0341241 | -0.7495425 |
| 33 | -0.0354105 | -0.7755507 |
| 34 | -0.036654 | -0.8017994 |
| 35 | -0.0378488 | -0.8282937 |
| 36 | -0.0389896 | -0.8550386 |
| 37 | -0.0400707 | -0.8820373 |
| 38 | -0.0410865 | -0.9092915 |
| 39 | -0.042031 | -0.9368016 |
| 40 | -0.0428984 | -0.964565 |
| 41 | -0.0436827 | -0.9925762 |
| 42 | -0.0443776 | -1.0208257 |
| 43 | -0.0449768 | -1.0492985 |
| 44 | -0.0454738 | -1.0779734 |
| 45 | -0.0458621 | -1.1068192 |
| 46 | -0.0461346 | -1.1357927 |
| 47 | -0.0462846 | -1.1648338 |
| 48 | -0.0463049 | -1.1938568 |
| 49 | -0.0461881 | -1.2227401 |
| 50 | -0.0459265 | -1.2513024 |
| 51 | -0.0455125 | -1.2792587 |
| 52 | -0.044938 | -1.3061037 |
| 53 | -0.0441948 | -1.3305788 |
| 54 | -0.0432743 | -1.3506508 |
| 55 | -0.0421677 | -1.3717234 |
| 56 | -0.040866 | -1.3941458 |
| 57 | -0.0393597 | -1.4180392 |
| 58 | -0.0376392 | -1.44354 |
| 59 | -0.0356944 | -1.4708021 |
| 60 | -0.033515 | -1.5 |
| 61 | -0.0310901 | -1.5313327 |
| 62 | -0.0284086 | -1.5650272 |
| 63 | -0.0254589 | -1.6013447 |
| 64 | -0.022229 | -1.640586 |
| 65 | -0.0187063 | -1.6831008 |
| 66 | -0.014878 | -1.7292967 |
| 67 | -0.0107305 | -1.7796524 |
| 68 | -0.0062498 | -1.8347336 |
| 69 | -0.0014212 | -1.8952141 |
| 70 | 0.0037704 | -1.9619021 |
|  |  |  |

**Table 1**. Values of V and G kernels for different SZA and nadir view (VZA=0).

**2.2.3 Surface BRDF File (MAIACRTLS)**

The *8-day* BRDF/albedo file includes:

* *Three parameters of RTLS BRDF model kiso, kv, kG* (here kiso = kL) in MODIS bands B1-B8 at *1km*. The retrievals represent cloud-free and low aerosol (AOD0.47<0.6) conditions;
* *Spectral surface albedo* in MODIS land bands B1-B8 at 1km. It represents instantaneous albedo defined as a ratio of reflected and incident narrowband radiative fluxes at the surface. Albedo is related to BRDF retrieval and also represents cloud-free and low aerosol conditions.

Please, keep in mind that the current Terra L1B data (based on current C6 re-processed MODIS data) still contain small residual calibration artifacts which sometimes become visible as stripes in both aerosol and surface products on the right part of the scan from about middle to the edge of scan.

**3. QA-related Comments (please read)**

In *daily* output files, the QA bit contains cloud mask, adjacency mask, surface type (the result of MAIAC dynamic Land-Water-Snow classification), and a surface change mask.

**3.1 Change in reported AOD for MAIAC AOT users:**

The current C6 MAIAC AOD is reported for two values of Cloud Mask in QA bit - Clear and Possibly\_Cloudy.

* Most applications should use AOD ONLY when QA.CloudMask = Clear, which guarantees high product quality.

The Possibly\_Cloudy value mostly originates from spatial analysis of retrieved AOD which assumes a certain degree of aerosol spatial homogeneity (this does not apply when MAIAC detects absorbing aerosols (smoke/dust)). This filter detects residual clouds and significantly improves aerosol product quality. However:

1. The work from air quality community (Allan Just and Itai Kloog et al.) showed that in some locations with high spatial aerosol variability such as Mexico City, this filter may systematically erase AOD retrievals in cloud-free conditions over certain urban areas.
2. This filter will also erase AOD for parts of spatially variable smoke or dust plumes where MAIAC Smoke/Dust detection failed.

For such user-specific applications (e.g., urban air quality analysis; fire smoke monitoring), we retain and report AOT when QA.CloudMask = Possibly\_Cloudy.

**3.2 Use of Adjacency Mask:**

This mask gives information about detected neighbor clouds or snow (in the 2-pixel vicinity). For general applications, we recommend to only use data with QA.AdjacencyMask=Normal. The value AdjacentToASingle CloudyPixel can also be used as it often represents false cloud detection. The other categories of AdjacencyMask are not recommended when using AOD. In land analysis, we do not recommend using values AdjacentToCloud and SurroundedByMoreThan6CloudyPixels.

**3.3 Selecting Best Quality BRF and AOD**

To select best quality BRF, one should apply the following QA filter:

QA.AOTLevel=low (0), QA.AdjacencyMask=Clear, and QA.AlgorithmInitializeStatus= initialized (0).

To select the best quality AOD, one should apply the following QA filter:

Over land: QA.CloudMask = Clear and QA.AdjacencyMask=Clear.

Over water: QA.QA\_AOD\_WATER=Best\_Quality.

# 4. MAIAC Data Specification

***4.1. Surface Reflectance (MAIAC[TA]BRF)***

|  |  |  |  |
| --- | --- | --- | --- |
| **SDS name** | **Data Type** | **Scale** | **Description** |
| Sur\_refl | INT16 | 0.0001 | Surface reflectance at 1km for bands 1-12 |
| Sigma\_BRFn | INT16 | 0.0001 | BRFn uncertainty over time, for bands 1-2 |
| Snow\_Fraction | INT16 | 0.0001 | Snow fraction |
| Snow\_Grain\_Size | INT16 | 0.0001 | Snow grain diameter |
| Snow\_Fit | INT16 | 0.0001 | Snow reflectance RMSE in band 1,5,7 |
| Status\_QA | UINT16 | n/a | QA bits |
| Sur\_refl\_500m | INT16 | 0.0001 | Surface reflectance 500m for band 1-7 (500m) |
| cosSZA | INT16 | 0.0001 | Cosine of Solar zenith angle (5km) |
| cosVZA | INT16 | 0.0001 | Cosine View zenith angle (5km) |
| RelAZ | INT16 | 0.01 | Relative azimuth angle (5km) |
| Scattering\_Angle | INT16 | 0.01 | Scattering Angle (5km) |
| SAZ | INT16 | 0.01 | Solar Azimuth Angle (5km) |
| VAZ | INT16 | 0.01 | View Azimuth Angle (5km) |
| Glint\_Angle | INT16 | 0.01 | Glint Angle (5km) |
| F0v | FLOAT32 | n/a | RTLS volumetric kernel (5km) |
| F0g | FLOAT32 | n/a | RTLS geometric kernel (5km) |

***4.2 Status QA definition for MAIAC[TA]BRF (16-bit unsigned integer)***

|  |  |
| --- | --- |
| **Bits** | **Definition** |
| 0-2 | **Cloud Mask**  000 --- Undefined  001--- Clear  010 --- Possibly Cloudy (detected by AOT filter)  011 --- Cloudy (detected by cloud mask algorithm)  101 -- - Cloud Shadow  110 --- Fire hot spot  111 --- Water Sediments |
| 3-4 | **Land Water Snow/Ice Mask**  00 --- Land  01 --- Water  10--- Snow  11 --- Ice |
| 5-7 | **Adjacency Mask**  000 --- Normal condition/Clear  001 --- Adjacent to cloud  010 --- Surrounded by more than 8 cloudy pixels  011 --- Adjacent to a single cloudy pixel  100 --- Adjacent to snow  101 --- snow was previously detected for this pixel |
| 8 | **AOD level**  0 --- AOD is low (<=0.6)  1 ---- AOD is high (> 0.6) or undefined |
| 9 | **Algorithm Initialize Status**  0 --- Algorithm is initialized  1 --- Algorithm is not initialized |
| 10 | **BRF retrieved over snow assuming AOD = 0.05**  0 --- no  1 --- yes |
| 11 | **Altitude >3.5km, BRF is retrieved using climatology AOD =0.02**  0 --- no  1 --- yes |
| 12-15 | **Surface Change Mask**  0000 --- no change  0001 --- Regular change Green up  0010 -- Big change green up  0011 --- Regular change Senescence  0100 --- Big change senescence  0101 --- Flooding  **Regular Change**: Relative change in Red and NIR nadir-normalized BRF is more than 5% but less than 15%  **Big Change :** Relative change in Red and NIR nadir-normalized BRF is more than 15% |

***4.3 Aerosol Optical Depth (MAIAC[TA]AOT)***

|  |  |  |  |
| --- | --- | --- | --- |
| **SDS name** | **Data Type** | **Scale** | **Description** |
| Optical\_Depth\_047 | INT16 | 0.001 | Blue band aerosol optical depth |
| Optical\_Depth\_055 | INT16 | 0.001 | Green band aerosol optical depth |
| AOT\_Uncertainty | INT16 | 0.0001 | AOD uncertainty |
| FineModeFraction | INT16 | 0.0001 | Fine mode fraction for ocean |
| Column\_WV | INT16 | 0.001 | Column Water Vapor (cm) |
| Injection\_Height | FLOAT32 | n/a | Smoke injection height (m above ground) |
| AOT\_QA | UINT16 | n/a | AOD QA |
| AOT\_MODEL | UINT8 | n/a | AOD model used in retrieval |
| cosSZA | INT16 | 0.0001 | Cosine of Solar zenith angle (5km) |
| cosVZA | INT16 | 0.0001 | Cosine of View zenith angle (5km) |
| RelAZ | INT16 | 0.01 | Relative azimuth angle (5km) |
| Scattering\_Angle | INT16 | 0.01 | Scattering Angle (5km) |
| Glint\_Angle | INT16 | 0.01 | Glint Angle (5km) |

***4.4 AOT QA definition for MAIAC[TA]AOT (16-bit unsigned integer)***

|  |  |
| --- | --- |
| **Bits** | **Definition** |
| 0-2 | **Cloud Mask**  000 --- Undefined  001--- Clear  010 --- Possibly Cloudy (detected by AOD filter)  011 --- Cloudy (detected by cloud mask algorithm)  101 -- - Cloud Shadow  110 --- hot spot of fire  111 --- Water Sediments |
| 3-4 | **Land Water Snow/ice Mask**  00 --- Land  01 --- Water  10--- Snow  11 --- Ice |
| 5-7 | **Adjacency Mask**  000 --- Normal condition/Clear  001 --- Adjacent to cloud  010 --- Surrounded by more than 8 cloudy pixels  011 --- Single cloudy pixel  100 --- Adjacent to snow  101 --- snow was previously detected on this pixel |
| 8-11 | **QA for AOT retrieval over Water**  0000 --- Best quality  0001 --- Water Sediments are detected  0010 --- AC over water done, but AOT>0.5  0011 --- There is 1 neighbor cloud  0100 --- There is >1 neighbor clouds  0101 --- no retrieval (cloudy, or whatever)  0110 --- no retrievals near detected or previously detected snow  0111 --- Climatology AOT: altitude above 3.5km(water) and 4.2km(land)  1000 --- no retrieval due to sun glint  1001 --- retrieved AOT is very low (<0.05) due to glint  1010 --- AOT within +-2km from the coastline is replaced by nearby AOD  1011 --- Land, research quality: AOT retrieved but CM is possibly cloudy |
| 12 | **Glint Mask**  0 --- no glint  1 --- glint (glint angle < 40°) |
| 13-14 | **Aerosol Model**  00 --- Background model (regional)  01 --- Smoke model (regional)  10 --- Dust model |
| 15 | **Reserved** |

***4.5 8-day BRDF model parameters (MAIACRTLS)***

|  |  |  |  |
| --- | --- | --- | --- |
| **SDS name** | **Data Type** | **Scale** | **Description** |
| Kiso | INT16 | 0.0001 | RTLS isotropic kernel parameter for band 1-8 |
| Kvol | INT16 | 0.0001 | RTLS volumetric kernel parameter  for band 1-8 |
| Kgeo | INT16 | 0.0001 | RTLS geometric kernel parameter  for band 1-8 |
| Sur\_albedo | INT16 | 0.0001 | Surface albedo  for band 1-8 |
| UpdateDay | UINT8 | n/a | Number of days since last update to the current day |

**5. Caveats and Known Problems**

1. The maximum AOD in the current look-up tables (LUT) is 4.0.
2. Current MAIAC LUTs are built assuming pseudo-spherical correction in single scattering which has reduced accuracy for high sun/view zenith angles. A reduced MAIAC performance is expected at solar zenith angles > 70°.
3. Current MAIAC may be missing several bright salt pans in the Sahara desert and Ethiopia/Somali regions. In such cases, it generates a persistent high AOD resulting in missing surface retrievals.
4. Because of inherent uncertainties of gridding on the coastline, the area of ±1-3 pixels from the coastline may contain frequent artifacts in cloud mask (over-detection), AOD (higher values) and surface BRF. Users should exercise caution in this case.

We are working to resolve these issues.

**REFERENCES**

C. Chen, Y. Knyazikhin, T. Park, K. Yan, A. Lyapustin, Y. Wang, B. Yang and R. B. Myneni, Prototyping of LAI and FPAR Algorithm with MODIS MultiAngle Implementation of Atmospheric Correction (MAIAC) data, *Rem. Sensing*, 2017, 9, 370; doi:10.3390/rs9040370.

Lyapustin, A., Y. Wang et al., Multi-Angle Implementation of Atmospheric Correction (MAIAC) Collection 6 Algorithm, in preparation.

Lyapustin, A., C. K. Gatebe, R. Kahn, R. Brandt, J. Redemann, P. Russell, M. D. King, C. A. Pedersen, S. Gerland, R. Poudyal, A. Marshak, Y. Wang, C. Schaaf, D. Hall, and A. Kokhanovsky, 2010: Analysis of Snow Bidirectional Reflectance from ARCTAS Spring-2008 Campaign. *Atmos. Chem. Phys.*, 10, 4359-4375.

Lyapustin, A., J. Martonchik, Y. Wang, I. Laszlo, S. Korkin, 2011a: Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 1. Radiative Transfer Basis and Look-Up Tables, *J. Geophys. Res*., 116, D03210, doi:10.1029/2010JD014985.

## Lyapustin, A., Y. Wang, I. Laszlo, R. Kahn, S. Korkin, L. Remer, R. Levy, and J. S. Reid, 2011b: Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 2. Aerosol Algorithm, *J. Geophys. Res*., 116, D03211, doi:10.1029/2010JD014986.

Lyapustin, A., Y. Wang, I. Laszlo, T. Hilker, F. Hall, P. Sellers, J. Tucker, S. Korkin, 2012: Multi-Angle Implementation of Atmospheric Correction for MODIS (MAIAC). 3: Atmospheric Correction. *Rem. Sens. Environ*. (2012), http://dx.doi.org/10.1016/j.rse.2012.09.002.

Lyapustin, A., Y. Wang, X. Xiong, G. Meister, S. Platnick, R. Levy, B. Franz, S. Korkin, T. Hilker, J. Tucker, F. Hall, P. Sellers, A. Wu, A. Angal (2014), Science Impact of MODIS C5 Calibration Degradation and C6+ Improvements, *Atmos. Meas. Tech.*, 7, 4353-4365, doi:10.5194/amt-7-4353-2014.

Meister, G., B. Franz, E. Kwiatkowska, and C. McClain (2012). Corrections to the Calibration of MODIS Aqua Ocean Color Bands derived from SeaWiFS Data, IEEE TGARS, 50(1), 310 – 319, doi: 10.1109/TGRS.2011.2160552.

Toller, G., X. Xiong, J. Sun, B. N. Wenny, X. Geng, J. Kuyper, A. Angal, H. Chen, S. Madhavan, and A. Wu, "Terra and Aqua Moderate-resolution Imaging Spectroradiometer Collection 6 Level 1B Algorithm", J. Applied Remote Sensing, 7(1), 2013, 0001;7(1):073557-073557. doi:10.1117/1.JRS.7.073557.

Wolfe, R. E., Roy, D. P., and Vermote (1998). E. MODIS Land Data Storage, Gridding, and Compositing Methodology: Level 2 Grid. *IEEE Trans. Geosci. Remote Sens.*, *36*,1324–1338.

We are looking forward to your comments, suggestions etc. which you may forward either to myself (Alexei.I.Lyapustin @nasa.gov) or to Yujie (Yujie.Wang@nasa.gov).

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