**MAIAC Data Release: Readme**

The original processing of MODIS Terra and Aqua data was performed on the NASA GSFC Supercomputer (NCCS).

In brief, 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. It starts with gridding MODIS L1B data to 1km resolution. MAIAC provides suites of 1km atmospheric and surface gridded products which include cloud mask, column water vapor and aerosol optical depth, type (background, biomass burning or dust), and Angstrom parameter, and surface spectral BRF, albedo and Ross-Thick Li-Sparse (RTLS) BRDF model parameters in 7 land bands. Surface BRFs in 5 unsaturated ocean bands are also provided. The 500m gridded land BRF is also produced for MODIS bands 1-7. The BRDF is currently reported every 8 days.

The current dataset presents data per orbit (we do not currently pack data in one daily file) and combines four hdf4 files detailed below in Tables 1-4. This data set is in 600x600km2 local tiles. The data files are arranged in sub-directories named with local tile numbers. The naming convention is generally in following format:

MAIAC[TA]XXX.hHHvVV.YYYYDDDHHMM.hdf,

where T represents Terra and A represents Aqua, XXX is the data file type (BRF, AOT, RTLS), HH and VV are the local tile number, YYYYDDDHHMM is the year, Julian day, hour and minute of the corresponding 5-minute MODIS L1B granule.

The atmospheric properties file (Table 2) contains aerosol optical depth at 0.466 μm and column water vapor (in cm). The Angstrom parameter obtained from the Blue (0.466 μm) and Red (0.67 μm) bands is not yet reliable, and the single scattering albedo, column water vapor and aerosol model are currently not available.

The Bidirectional Reflectance Factor (BRF, also called "surface reflectance") is given at 1km resolution for MODIS bands 1-12, and at gridded 500m resolution in MODIS land bands 1-7. Since many tasks, e.g. change detection, require geometry normalization, we also provide the RTLS volumetric (Fv) and geometric-optics (Fg) kernel function values for a given geometry (at 5km resolution), so that the user could easily implement such normalization using the provided in file 3 (see Table 3) spectral BRDF kernel weights {kL, kV, kG} based on the following formula (see Eqs. (6) and (8) from Lyapustin et al., 2012a):

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

This formula re-normalizes BRF from a given view geometry to the fixed geometry of nadir view and 45° sun zenith angle. One can easily modify the above coefficients to adapt normalization to other angles, if necessary.

Following is a table of the coefficients for different solar zenith angle, and nadir view.

|  |  |  |
| --- | --- | --- |
| SZA | Fv | Fg |
| 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 |

In every file, the QA bit contains cloud mask, the result of MAIAC dynamic Land-Water-Snow classification, and a surface change mask.

The BRDF/albedo file (Table 3) contains RTLS kernel coefficients (here kiso = kL) for each 1km grid cell and a value of spectral albedo (defined conventionally as a ratio of reflected to the incident radiative narrowband flux at the surface level).

Finally, the VI file (Table 4) contains 8-day composite NDVI and EVI. Both VIs are calculated using re-normalized BRF (BRFn) to correct for BRDF effect. As a comparison, we also include 8-day composite NDVI without BRDF correction. For user’s convenience, 8-day composite BRFn for band 1-4 is also given in this file.

Please, keep in mind that the current Terra L1B data (based on current C6 re-processed MODIS data) still contain residual calibration artifacts which 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.

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).

We acknowledge the support from NCCS and MODIS LAADS in accommodating processing and data archive.

**MAIAC Data Specification**

***1. Surface Reflectance (MAIA[TA]CBRF)***

|  |  |  |  |
| --- | --- | --- | --- |
| **SDS name** | **Data Type** | **Scale** | **Description** |
| Sur\_refl | INT16 | 0.0001 | Surface reflectance 1km for band 1-12 |
| Sigma\_BRFn | INT16 | 0.0001 | BRFn uncertainties over time, for band1,2 |
| Snow\_Fraction | INT16 | 0.0001 | Snow fraction |
| Snow\_Grain\_Diameter | INT16 | 0.001 | 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) |
| Fv | FLOAT32 | 0.0001 | RTLS volumetric kernel (5km) |
| Fg | FLOAT32 | 0.0001 | RTLS geometric kernel (5km) |

*Status\_QA definition (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 --- 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  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 | **AOT level**  0 --- AOT is low (<=0.6)  1 ---- AOT is high (> 0.6) or undefined |
| 9 | **Algorithm Initialize Status**  0 --- Algorithm is initialized  1 ---- Algorithm is not initialized |
| 10 | **BRF retrieved over snow, use AOT = 0.05**  0 --- no  1 --- yes |
| 11 | **Altitude >3.5km, BRF is retrieved with AOT =0.01**  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% |

***2. Aerosol Optical Thickness (MAIA[TA]CAOT)***

|  |  |  |  |
| --- | --- | --- | --- |
| **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 | AOT uncertainties |
| FineModeFraction | INT16 | 0.0001 | Fine mode fraction for ocean |
| Column\_WV | INT16 | 0.001 | Column Water Vapor |
| Injection\_Height | FLOAT32 | n/a | Smoke injection height |
| AOT\_QA | UINT16 | n/a | AOT QA |
| AOT\_MODEL | INT16 | 0.001 | AOT 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) |

*AOT\_QA definition (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 --- 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  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  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 snow  0111 --- no retrievals for altituide more than 3.5km  1000 --- no retrieval due to sun glint  1001 --- retrieved AOT is very low (<0.05) due to low Coxmunk angle  1010 --- AOT within +-2km from the coastline is replaced by nearby AOT |
| 12 | **Glint Mask**  0 --- glint is not detected  1 --- glint is detected |
| 13-14 | **Aerosol Model**  00 --- Background model  01 --- Smoke model  10 --- Dust model |
| 15 | **AOT Quality FLAG**  0 --- Good  1 --- Possible cloud contamination |

***3. 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 |
| Update\_Day | UINT8 | n/a | Number of days since last update to current day |

***4. 8-day composite NDVI, EVI and BRFn (MAIACVI)***

|  |  |  |  |
| --- | --- | --- | --- |
| **SDS name** | **Data Type** | **Scale** | **Description** |
| NDVI | INT16 | 0.0001 | 8-day composite NDVI |
| NDVI\_N | INT16 | 0.0001 | 8-day composite BRDF corrected NDVI |
| EVI | INT16 | 0.0001 | 8-day composite BRDF corrected EVI |
| Surf\_refl\_1 | INT16 | 0.0001 | 8-day composite BRF normalized to SZA=45º, nadir view, Band 1 |
| Surf\_refl\_2 | INT16 | 0.0001 | 8-day composite BRF normalized to SZA=45º, nadir view, Band 2 |
| Surf\_refl\_3 | INT16 | 0.0001 | 8-day composite BRF normalized to SZA=45º, nadir view, Band 3 |
| Surf\_refl\_4 | INT16 | 0.0001 | 8-day composite BRF normalized to SZA=45º, nadir view, Band 4 |

**MAIAC Data File Name Convention and FTP directory structure**

***The naming convention is generally in following format:***

MAIACXXX.hHHvVV.YYYYDDDHHMM.hdf,

where XXX is the data file type (BRFM, AOT, RTLS), HH and VV are the local tile number, YYYYDDDHHMM is the year, Julian day, hour and minute of the corresponding 5-minute MODIS L1B granule.

***The data files for each sensor are arranged in sub-directories as following:***

**Region name**

***………***

***h07v07***

***h00v00***

***………***

***200000***

***2014***

***………***

***200000***

***2014***

***………***

***200000***

***2014***

There are two levels subdirectories under the root directory: 1) tile ID, and 2) year.

REFERENCE

Lyapustin, A., S. Korkin, Y. Wang, B. Quayle, and I. Laszlo, 2012b: Discrimination of biomass burning smoke and clouds in MAIAC algorithm, Atmos. Chem. Phys., 12, 9679–9686, doi:10.5194/acp-12-9679-2012.

Lyapustin, A., Y. Wang, I. Laszlo, T. Hilker, F. Hall, P. Sellers, J. Tucker, S. Korkin, 2012a: 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.

Hilker, T., A. I. Lyapustin, C. J. Tucker, P. J. Sellers, F. G. Hall, Y. Wang, 2012: Remote Sensing of Tropical Ecosystems: Atmospheric Correction and Cloud Masking Matter. *Rem. Sens. Environ.* (2012), http://dx.doi.org/10.1016/j.rse.2012.08.035.

Emili, E., A. Lyapustin, Y. Wang, C. Popp, S. Korkin, M. Zebisch, S. Wunderle, and M. Petitta, 2011: High spatial resolution aerosol retrieval with MAIAC: Application to mountain regions, *J. Geophys. Res.*, 116, D23211, doi:10.1029/2011JD016297.

Lyapustin, A., J. Martonchik, Y. Wang, I. Laszlo, S. Korkin, 2011: 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, 2011: Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 2. Aerosol Algorithm, *J. Geophys. Res*., 116, D03211, doi:10.1029/2010JD014986.