A New High Resolution Aerosol Dataset from Algorithm MAIAC

Alexei Lyapustin, GSFC, code 613
Y. Wang (UMBC), S. Korkin (USRA)

October 15, 2014
MAIAC = Time Series + Spatial Analysis
MAIAC: Standard and New Features

- Anisotropic surface model;
- Retrieval of Spectral Regression Coefficient;
- Detection and accommodation of seasonal and rapid surface change;
- Storing “static” (surface) information;
- Products: WV, CM, AOT, AE (over dark surfaces) and aerosol type (background/smoke/dust – in progress) @1km resolution and surface suite (spectral BRDF model, BRF (SR), albedo).

New Features

- Removed blockiness (25km) of AOT and SR images;
- Provide uncertainty of AOT;
- Aerosol type classification (background/smoke/dust);
- Improvements in cloud detection.
Old: Multi-day minimization over 25x25km$^2$ blocks

New: Minimum Reflectance Method:
- We can express measured B3 radiance as a function of 2.1$\mu$m BRDF:
  \[ L^{B3} \approx D + L_s(b\rho^{B7}) \]
- Compute $b$ for the background aerosol (AOT~0.05);
- Blue band is “dark”, aerosols increase SRC ($b$);
- Select SRC as min over $\Delta T$;
- Run 2 lines of SRC update: each line initializes over 2 months, and SRC is updated monthly
Example, incl. coastal and inland water

AOT_{0.47}
Aerosol Type Discrimination (Smoke/Dust)

Lyapustin, A. et al., 2012: Discrimination of biomass burning smoke and clouds in MAIAC algorithm, ACP, 12, 9679–9686.

Phys. principles (~OMI) – **enhanced shortwave absorption** (Red →Blue →DB)

\[ R_{\lambda}^{\text{Aer}} = R_{\lambda}^{\text{Meas}} - R_{\lambda}^{\text{Molec}} - R_{\lambda}^{\text{Surf}}(\tau^a) \] - proxy of aerosol reflectance

1) \( n_i \) increases \( R \rightarrow DB \) for OC (smoke) and dust;

2) Multiple scattering, and absorption, increase \( R \rightarrow DB \), for absorbing aerosols.

\[ \delta_\lambda = R_{\lambda}^M - R_{\lambda}^T(\tau_{0.47}^a = 0.05) \]

<table>
<thead>
<tr>
<th>Model</th>
<th>Abs.</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backgr.</td>
<td>No</td>
<td>Small</td>
</tr>
<tr>
<td>Smoke</td>
<td>Yes</td>
<td>Small</td>
</tr>
<tr>
<td>Dust</td>
<td>Yes</td>
<td>Large</td>
</tr>
</tbody>
</table>
Idaho/Wyoming – Yosemite Fires (08-2013)
Idaho/Wyoming – Yosemite Fires (08-2013)
Idaho/Wyoming – Yosemite Fires (08-2013)
On Spectral Invariance Assumption

SRC algorithm assumes the BRDF shapes in Blue and SWIR are the same:
\[ \rho_{ij}^{\text{Blue}} = b_{ij} \rho_{ij}^{B7} \]. Are they?

- The 1st order of scattering must be the same as 3D structure of surface is the governing property:
  \[ \rho_{B3}^{(1)} = b \rho_{B7}^{(1)} \]

- The total reflectance:
  \[ \rho_{\lambda} = \rho^{(1)} + \rho^{(2)} + \rho^{(3)} \ldots \approx \rho^{(1)} + \frac{\eta^2}{1 - \eta} \]

  where \( \eta \approx \int \int \rho^{(1)}(s, s')dsds' \) is “spherical” albedo.

- With linear RTLS model, \( \eta = k_L^{(1)} + k_v \nu_v + k_g \nu_g \).

- Further, the RTLS parameters become:
  \[ \{ k_L^{(1)} + \frac{\eta^2}{1 - \eta}, k_v, k_g \} \]

Implications:

- Improve BRDF shape for aerosol retrievals;
- Full AC (RTLS inversion) only needed in B7 (pure LC types – e.g. deserts)
Example: Flagstaff, AZ

DOY 129-133, 2009

What is Dark/Bright Surface?

\[ \delta R^{TOA} = R'_\tau \delta \tau + R'_\rho \delta \rho \]

We can assess SR uncertainty (from TMS analysis for stable surface):

\[ \delta \rho \sim 0.002 - 0.005 \]

\[ \delta \tau = R'_\rho \delta \rho / R'_\tau \]
MAIAC did not show decreased performance over urban surfaces over B-W area.
San Joaquin Valley 2012-2013

DOY: 329, 331, 2012

Yosemite Fires, Aug. 2013

248

250

251

252
C5 Trends: Aerosol and Clouds

DT Aerosol: AOD and AE (R. Levy)

Cloud Opt. Properties: COT (S. Platnick)

Levy et al. (2010), Global evaluation of the Collection 5 MODIS dark-target aerosol products over land, ACP.

Koukouli et al. (2010), Signs of a negative trend in the MODIS aerosol optical depth over the Southern Balkans, Atm. Environ.
C6+: MODIS de-trending and X-calibration

- MODIS C6 L1 removed major calibration trends of Terra;
- Remained: Terra polarization sensitivity (PC); Applied PC algorithm developed by GSFC OBPG => found residual trends of T&A;
- Used CEOS desert cal. sites => TOA reflectances ($R_n$) for fixed geometry (VZA=0°, SZA=45°);
C6+: MODIS de-trending and X-calibration

- Use of $R_n$ allows us to X-calibrate Terra vs Aqua!
- Based on C6+, MAIAC processes Terra & Aqua jointly.

### Data Structure

**AOT_QA definition**  
(16-bit unsigned integer)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Cloud Mask</td>
</tr>
<tr>
<td></td>
<td>000 --- Undefined</td>
</tr>
<tr>
<td></td>
<td>001 --- Clear</td>
</tr>
<tr>
<td></td>
<td>010 --- Possibly Cloudy (detected by AOT filter)</td>
</tr>
<tr>
<td></td>
<td>011 --- Cloudy (detected by cloud mask algorithm)</td>
</tr>
<tr>
<td></td>
<td>101 --- Cloud Shadow</td>
</tr>
<tr>
<td>3-4</td>
<td>Land Water Snow/Ice Mask</td>
</tr>
<tr>
<td></td>
<td>00 --- undefined</td>
</tr>
<tr>
<td></td>
<td>01 --- Land</td>
</tr>
<tr>
<td></td>
<td>10 --- Water</td>
</tr>
<tr>
<td></td>
<td>11 --- Snow/Ice</td>
</tr>
<tr>
<td>5-7</td>
<td>Adjacency Mask</td>
</tr>
<tr>
<td></td>
<td>000 --- Normal condition</td>
</tr>
<tr>
<td></td>
<td>001 --- Adjacent to cloud</td>
</tr>
<tr>
<td></td>
<td>010 --- Surrounded by more than 8 cloudy pixels</td>
</tr>
<tr>
<td></td>
<td>011 --- Single cloudy pixel</td>
</tr>
<tr>
<td></td>
<td>100 --- Adjacent to snow</td>
</tr>
<tr>
<td></td>
<td>101 --- snow was previously detected on this pixel</td>
</tr>
</tbody>
</table>

**Aerosol Optical Thickness**  
(MAIACAOT)

<table>
<thead>
<tr>
<th>SDS name</th>
<th>Data Type</th>
<th>Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical_Depth_Land</td>
<td>INT16</td>
<td>0.001</td>
<td>Blue band aerosol optical depth</td>
</tr>
<tr>
<td>AOT_Uncertainty</td>
<td>INT16</td>
<td>0.0001</td>
<td>AOT uncertainties</td>
</tr>
<tr>
<td>Angstrom_Para</td>
<td>INT16</td>
<td>0.001</td>
<td>Angstrom parameter</td>
</tr>
<tr>
<td>SSA</td>
<td>INT16</td>
<td>0.001</td>
<td>Single Scattering Albedo</td>
</tr>
<tr>
<td>Column_WV</td>
<td>INT16</td>
<td>0.001</td>
<td>Column Water Vapor</td>
</tr>
<tr>
<td>AOT_QA</td>
<td>UINT16</td>
<td>n/a</td>
<td>AOT QA</td>
</tr>
</tbody>
</table>

1. **Finishing science development**;
2. **Plan is to re-process MODIS Terra-Aqua by the end of this year on MODAPS**;
3. **Operational code – early next year**;
4. **In 1-4 weeks: North and South Americas and Europe on NCCS (free access)**