GOES-16 ABI
AOD Algorithm and Product Validation

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CEOS AC-VC-14 & GEO-CAPE Joint Meeting,
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• ABI aerosol optical depth (AOD) algorithm
• ABI AOD product
• Evaluation
• The “Enterprise” AOD algorithm
• Synergy of “geo” and “polar” AOD
• Summary
• Useful documents
The ABI Aerosol Optical Depth (AOD) Algorithm
• ABI “aerosol” channels: 1, 2, 3, 5 and 6
  • Narrow channels
  • Relatively weak absorption by gases
  • Onboard calibration!
<table>
<thead>
<tr>
<th>ABI Band</th>
<th>Central Wavelength (µm)</th>
<th>Retrieval</th>
<th>Internal Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Land</td>
<td>Water</td>
</tr>
<tr>
<td>1</td>
<td>0.470</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.640</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>0.865</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>1.378</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.610</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.250</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>14</td>
<td>11.200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GOES-R AOD Algorithm (1)
Surface Reflectance

**Land**
- surface contribution is retrieved using the dark-target approach

\[ \rho_{0.47\lambda_{0.64}} = C(NDVI, \theta_s) \times \rho_{2.25} \]

- No retrieval for bright land

**Water**
- surface contribution is calculated
  - water-leaving radiance (Lambertian)
  - whitecap (Lambertian)
  - sunglint (bi-directional)

- No retrieval in glint
### GOES-R AOD Algorithm (2)

**AOD Retrieval**

- Separate algorithms for land and water.
- MODIS and early VIIRS heritage. ([Tanre et al., 1997; Remer et al., 2005; Levy et al., 2007, Vermote et al., 2007](#))
- Simultaneous retrieval of AOD and aerosol type by comparing calculated and observed reflectances at multiple wavelengths.

**Diagram**

- Water: 4 fine and 5 coarse mode models
- Land: generic, dust, smoke and urban models
## Internal Tests

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quality Level</th>
<th>Applies to</th>
<th>Detected by</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Retrieval</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Invalid input data</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cloud</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Snow/Ice</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ephemeral Water</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Sun Glint</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bright Land Surface</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOD Out of Range</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Low Sun (solzen &gt; 80°)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Low Satellite (satzen &gt; 60°)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E &amp; I cloud tests contradict</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Coastal</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shallow Inland Water</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Inhomogeneity</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>High Residual</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cloud/Snow Adjacency</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shallow Ocean</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Probably Clear</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Medium Inhomogeneity</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Medium Residual</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
AOD Product

• Products in file:
  • 550-nm Aerosol Optical Depth for Full Disk and CONUS in range -0.05 to +5
  • Quality flag (0=good; 1=medium, 2=low, 3=not produced)
  • Mean, max, min and standard deviation of 550-nm AOD (and in bands used for AOD retrieval)

• In Beta maturity status since May 24, 2017
  • Beta product is minimally validated and may still contain significant errors; not recommended for operational use.
  • Disclaimer: The GOES-16 data are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

• Availability:
  • NOAA’s Comprehensive Large Array-Data Stewardship System at https://www.class.ncdc.noaa.gov after product passed Provisional Review (review scheduled for June 2018)
5-minute Medium+High Quality AOD
Quality Flags (Example)

H  High
M  Medium
L  Low
L1  Contradicting Cloud Masks
L2  Low Satellite Angle
L3  Low Sun Angle
L4  Out of Spec Range
L5  Coastal Area
L6  Shallow Inland Water
L7  High Residual
L8  High Inhomogeneity
N  No Retrieval
N1  Invalid Input
N2  Cloud
N3  Snow
N4  Bright Land Surface
N5  Sun Glint
Evaluation
AERONET:

- Ground-based Aerosol Robotic Network (AERONET) provides high-quality comprehensive data of aerosol properties. *(Holben et al. 1998)*
- Widely used for evaluating satellite retrievals and model simulations in the aerosol community.
Aerosol Optical Depth at 550nm

07/31/2017 at 15:45 UTC
High Quality AOD

Aerosol Optical Depth at 550nm

07/31/2017 at 15:45 UTC

CEOS AC-VC-14 & GEO-CAPE Joint Meeting, May 1-4, 2018, College Park, MD
Validation with AERONET

- Time period: 04/29/2017 – 03/24/2018
- High quality AOD
- Bias and StDev: mean and standard deviation of ABI-AERONET differences
• Co-located ABI-AERONET matchup data for 04/29/2017-03/24/2018.
• Retrieval generally follows AERONET.
• Apparent seasonal bias over land; slight positive bias but no apparent trend.
High-Quality AOD Time Series
Selected Sites

Co-located ABI-AERONET CONUS dataset for 03/06/2018 – 04/26/2018.
Diurnal Changes
Matchup data for 04/29/2017-03/24/2018

LAND

WATER

GSFC

Wallops-land
“Synergy” of Geostationary and Polar AOD

Filling in sunglint and other holes in geo AOD
S-NPP and NOAA-20 from GOES-16
2018.04.19

Correct land/water mask leads to inferior synthetic green band in RGB

Missing band 2 reflectance

GOES-16 ABI and S-NPP VIIRS AOD
GOES-16 ABI and S-NPP VIIRS AOD

2018.04.19

• ABI 19:45 UTC
• S-NPP 19:25-20:05 UTC
• Combined ABI and VIIRS AOD makes more complete AOD field
GOES-16 ABI and NOAA-20 VIIRS AOD

ABI 20:30 UTC

2018.04.19

NOAA-20 20:15-20:55 UTC
GOES-16 ABI and NOAA-20 VIIRS AOD

2018.04.19

• ABI 20:30 UTC
• NOAA-20 20:15-20:35 UTC
• Combined ABI and VIIRS AOD makes more complete AOD field
“Enterprise (EPS)” AOD Algorithm

- STM’s goal is to update/switch to “Enterprise” (EPS) version.
- Runs operationally at NOAA since July 2017 with VIIRS on Suomi-NPP (and on NOAA-20)
- For land, combines two flavors of the Dark Target method
  - **SW-scheme**: more accurate 0.488 µm (M3) surface reflectance from 0.672 µm (M5) for low AOD
  - **SWIR-scheme**: more accurate 0.488 µm (M3) surface reflectance from 2.25 µm (M11) for high AOD
- Retrieves over bright snow-free land using 0.1°x0.1° database of M3/M5 and M1/M5 surface reflectance ratios
Summary

• ABI AOD algorithms over water and land are based on MODIS and VIIRS heritages.

• CONUS/Full disk AOD is every 5/15 minutes.

• As of now (05/04/2018) GOES-16 ABI AOD is beta

• Provisional: Jun 2018; Full validated: Sep 2018

• STM goal is to switch algorithm from Baseline to “Enterprise (EPS)” (AOD over snow-free bright surface; improved retrieval of high AOD, etc.)

• Working on deriving solar & view angle dependent surface reflectance relationships (need large volume of data)
Useful Documents

At [http://www.goes-r.gov/resources/docs.html](http://www.goes-r.gov/resources/docs.html):

- Advanced Baseline Imager (ABI) Fact Sheet
- ABI Bands Quick Information Guides
- ABI Suspended Matter/Aerosol Optical Depth and Aerosol Size Parameter – Algorithm Theoretical Basis Document
- GOES-R Product Definition and Users’ Guide (PUG) Volume 5 (L2+ Products)
Impact of 7% ABI Band 2 Calibration Bias
All-Quality 550-nm AOD

07/31/2017 at 15:45 UTC

From Unchanged Reflectances

Reduced-Unchanged Difference
Reduced vs. Unchanged

LAND

WATER

AOD550 from current reflectance vs. AOD550 from reduced reflectance for LAND and WATER.

For LAND:
- Y = 0.781 * X + 0.030
- Mean Difference = -0.013
- StdDev = 0.307

For WATER:
- Y = 0.985 * X - 0.013
- Mean Difference = -0.018
- StdDev = 0.080
Land Aerosol Model Selection
Unchanged Band 2 Reflectance

With current ABI Band 2 reflectance
Land Aerosol Model Selection
Reduced Band 2 Reflectance

With reduced ABI Band 2 reflectance