Synergy of Atmospheric Aerosol Information: The importance of “getting it right”.

Robert C. Levy (SSAI @ 613.2)

Contributors: S. Mattoo, L. Remer, R. Kleidman, R. Kahn, S. Gassó, G. Leptoukh...
MODIS Aerosol Algorithm

Modeled and Observed Reflectance from MODIS
July 21, 14:50: $\tau_{865} = 0.48$

Aerosol Retrieval Bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Bandwidth</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>620-670 nm</td>
<td>250 m</td>
</tr>
<tr>
<td>2</td>
<td>841-876 nm</td>
<td>250 m</td>
</tr>
<tr>
<td>3</td>
<td>459-479 nm</td>
<td>500 m</td>
</tr>
<tr>
<td>4</td>
<td>545-565 nm</td>
<td>500 m</td>
</tr>
<tr>
<td>5</td>
<td>1230-1250 nm</td>
<td>500 m</td>
</tr>
<tr>
<td>6</td>
<td>1628-1652 nm</td>
<td>500 m</td>
</tr>
<tr>
<td>7</td>
<td>2105-2155 nm</td>
<td>500 m</td>
</tr>
</tbody>
</table>

- Ocean: Inversion of $6\lambda$ excludes Band 3.
- balanced on Band 2
- Land: Inversion of $3\lambda$ includes Band 3
Evaluation of the C005 Aerosol Product
**Validation:** quantifying the expected error

First steps:

- Pictures look good
- Compare both land and ocean products to AERONET, separately
- Validation: 66% are within “Expected Error” (EE) defined as
  - Land: \( \pm(0.15\tau + 0.05) \)
  - Ocean: \( \pm(0.05\tau + 0.04) \)

AERONET: Level 2 (Quality Assured)

May 4, 2001; 13:25 UTC
Level 2 “Granule”

LAND

0.67

0.22

OCEAN

GLINT

MASK

AERONET: Level 2 (Quality Assured)

---

Levy et al., ACP 2010
C005 Validation Summary

• MODIS C005 dark-target AOD (Land and Ocean) is “validated”,
  – 66% within defined error envelope, globally
  – Generally, more tightly constrained than C004

• In other words, no major surprises!

• Therefore, we analyzed C005 data to answer some basic questions about global aerosol...
Q1: What is global mean AOD?
A1: It depends on the instrument and the Collection

- We expected C005 mean = C004 mean
- C005 Terra > C004 Terra and C005 Terra > C005 Aqua
- *This is result of changing L1B observational input!*  

Remer et al., JGR 2009
Q2: Is global aerosol increasing or decreasing?
Over ocean,
- **Terra** and **Aqua** are increasing (+0.001/yr), and are both significant at 95%
- **Terra** > **Aqua** by +0.01 (10%).

Over land,
- **Terra** decreases (-0.004/yr), and is significant at 95% level
- **Aqua** increases (+0.0007/yr), and is not significant at 95% level
• **Terra – Aqua** is the same everywhere on the globe!
  • Ocean: Terra-Aqua = 0.01;
  • Land: Terra-Aqua changes from +0.02 to -0.01.

• Details of aggregation and sampling are NOT primary driver
• All-regional behavior suggests not local diurnal cycle
Terra ≠ Aqua (2)

Terra-Aqua flips sign between 2003 and 2006.
Performance of MODIS instruments may be changing...

Trends of MODIS-AERONET “agreement” over time (land)

- Over land: 14 AERONET sites with >7 years of data (plotted)
- Metric decreases for Terra (R = -0.275, significant), which means that in <2004, MODIS overestimates AOD, but >2004 MODIS underestimates! No trend for Aqua.
- AOD Trends over land may be actually changes of instrument “bias”.
- Same games played over ocean, show negligible increase of both instruments versus AERONET, with Terra biased high and Aqua biased low.
Zhang and Reid found up trends for both Terra and Aqua – MODIS over ocean.

There was no apparent trend for MISR, also flying on Terra.

They corrected MODIS for biases, including cloud fraction and changes in MODIS vs AERONET “agreement”:

They concluded that there is “negligible trend in AOD of 0.0003 / per year”.

Apparent MODIS “trends” may be “jumps”, related to artifacts of calibration.
AOD trends and trends of instrument calibration

Linking $\Delta \tau$ to $\Delta \rho$ (Terra-Aqua)

$\Delta \rho = 0.001 \implies \Delta \tau = 0.01$

- Band #3 (466 nm) is reported but not used for ocean retrieval. Band #3 is used over land.
  - Land trend of $\Delta \tau$ consistent with $\Delta \rho$
- Band #2 (859 nm) is central for ocean retrieval
  - No trend, but consistent offset

- Band #3 drives Terra-Aqua trend over land
- Band #2 drives Terra-Aqua offset over ocean
- Effects are non-linear, so other bands must also be studied
- Maybe not “calibration” per se, but other artifacts of sensor degradation (meeting with MCST and alg. developers tomorrow!)
Example of C5-C4 L1B change

Changes in L1B reflectance: Terra, C5-C4

λ ≥ 0.86 µm: Became Brighter (Δρ ~ 0.0002)
λ ≤ 0.66 µm: Became Darker (Δρ ~ -0.0001)
Note variability relative to nadir and glint

Impact on retrieved AOD: Terra, C5-C4

Impact varies spectrally, and depends on specific geometry and aerosol/surface conditions.
Means and Trends

Surprises in C005

• Calibration differences and drifts are sufficient to explain a portion of the apparent MODIS trends and Terra/Aqua discrepancies.

• In cooperation with MODIS calibration team, we are searching the instrumental record, and identifying issues that we must correct for and deal with.

• *Data producers (us) and data users (you) must be aware of potential artifacts in the data.*

• Case studies and other inter-comparisons are necessary for interpreting the satellite data correctly.
Looking ahead to Collection 6
Other changes for C006

- The C005 product was good, but it can be better
  - Plenty of changes for aerosol algorithm (both land and ocean)
  - LUT consistency (wavelengths, Rayleigh optical depth).
  - QA consistency: Make sure QA is assigned correctly

- Many new products as well (for another talk)
C006 development paradigm is:

- We know that C006 Radiance product will be different than C005.
- Have MCST produce test versions of C006 radiances over many days, months, and seasons throughout both Terra and Aqua lifetimes.
- Use the production team (LAADS) to make many tests, on different combinations of C005 and C006 algorithms/radiances
- Characterize C006 aerosol product *before* becoming operational
“Getting it right” (or at least well characterized)

C6-C5: Algorithm only

Global Correction of Rayleigh optical depth:
• 0.01 increase over land
• 0.01 decrease over ocean

Allowing SZA up to 84°:
• high latitude coverage

New aerosol model map boundaries over land:
• increase over SE Asia and N. American plains
• decrease over Brazil savanna and Australia

C6-C5: Algthm + Calibration

Calibration:
• Cuts over land-increase in half

Multiple wind speed LUT Over ocean
• >0.02 decrease near glint and where large wind speed (e.g. roaring 40s in SH)

In collaboration with LAADS, via B. Ridgway
Predicted impacts from LAADS tests

“308” (C5 calibration, C5 algorithm) versus “311” (C6, C6)
Four whole months, Jan and July, 2003 and 2008.

Land: Terra-Aqua “trend” would remain in C006
Ocean: Terra-Aqua “offset” would remain in C006
Getting it right

• C006 production will begin sometime this year.

• Our product is part of a “food chain”

• Our goal is to characterize the aerosol product before it becomes operational

• Part of our job is to ensure that Science and Nature papers are not published because of artifacts of the instruments and/or algorithms!
Our own evaluation of C005 is ongoing
We have found “surprises” in the aerosol statistics
People are writing *Science/Nature* papers about aerosol statistics
C005 surprises seem to be related to calibration and instrument degradation artifacts.
Summary

• We don’t want surprise artifacts in C006 data
• This time, we are doing testing, testing, and more testing before C006 is operational
• At least we want to know what the issues are
• Is the problem one of “polarization correction” for Band #3?
• What about offsets in Band #2?
• Do other groups care?
• How do we fix? Purpose of this meeting
Thank you