Global and Regional Retrieval of Aerosol from MODIS

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modis-atmos.gsfc.nasa.gov
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Why study aerosols?

CLIMATE
AIR QUALITY
HUMAN HEALTH
EARTH HEALTH

IPCC, 2001

CLIMATE VISIBILITY
AIR QUALITY
HUMAN HEALTH
EARTH HEALTH

Aerosol Measurements

IN-SITU (Perturbed)

Pump/Filter:
Size/Concentration

Nepholometer/PSAP:
Scatt/Absorb -> Concentration/Size

REMOTE (Ambient)

Satellite:
Scattering -> AOD/Size

Sunphotometer:
Extinction/Scattering -> AOD/Size

Aerosol Types/Properties

Of interest here

UV BGR NIR IR

2.5µm
Aerosol Scattering ~ 90% total Extinction

Depends on number, size and composition of intervening aerosol

\[ \alpha = \frac{m d}{\lambda} \]

Maximum efficiency when aerosol size \( \approx \) wavelength

Spectrally dependent Optical depth \( \tau \)

Spectral optical properties of aerosol

Scientific Data

Atmosphere: Cloud and Aerosol
Ocean: Color, Chlorophyll, Temp
Land: Vegetation, Change, Fires

Aerosol Retrieval

Over Land: (10 km x 10 km)
\( \bullet \) (AOD) at 3 \( \lambda \)
\( \bullet \) Aerosol size/type
Over Ocean: (10 km x 10 km)
\( \bullet \) (AOD) at 7 \( \lambda \)
\( \bullet \) Aerosol size/type

The Satellite Signal

Gas + Aerosol scattering
\( l(\mu, \lambda) \)
Indirect Transmission
(adjacency effect)

Direct Transmission
(of surface albedo)

\( T(\mu) = e^{-\tau} + I_1(\mu) \)

Multiple Reflection

\( T(\mu) = \frac{T \mu}{\cos \theta} + T_d(\mu) \)

\( T = \) Transmission
\( \tau = \) optical depth
\( \mu = \cos \theta \)
\( T_d = \) direct trans

\( \text{clear-sky conditions.} \)

Adapted from Tanre et al. (1979), (1981), (1983).
• Aerosol is transparent to Mid-IR, thus the surface properties are observed.
• Surface reflectance in the visible is function of Mid-IR
  \[ \tau_{0.66} \sim [\rho_{0.66} - 0.5\rho_{2.1}] \]
  \[ \tau_{0.67} \sim [\rho_{0.67} - 0.25\rho_{2.1}] \]
• Aerosol type/optical properties are assumed based on season and location
• Single channel retrievals are performed in red and blue, then dust is “added” to fit spectral dependence.

Y. J. Kaufman
Level 3 Daily -----> Level 3 Monthly

Level 3 (monthly)
• 1° x 1° (regular lat/long)
• Daily values are “averaged”
• Statistics are produced
  • Mean, Stdev, Pixel Count,
  • Quality Control / Confidence

Comparison with Climate models

MODIS AOD “Validation”
Comparison with sunphotometer

Global MODIS AOD “Validation”

Plume Transport and Spatial Variability

66% of retrievals over OCEAN fall within expected uncertainty

71% of retrievals over LAND fall within expected uncertainty

Remer et al., 2003

Sunphotometer AOD
0.67

Interesting Plumes 2000-2003

King et al., 2003
MODIS (column) vs PM (surface)

Monthly mean correlations of 0.9 in Southeast (Wang & Christopher)
Correlation nationally (Engle-Cox et al.)

A. CHU

But... land retrieval is not perfect

• Positive offset
• Slope less than one
• Offset in blue (470 nm) even worse, like 0.12.
• Only 60% within error bars over U.S. East Coast

MUST STUDY REGIONALLY!

Land retrievals too high for low AOD

August 1, 2001

AOD 0.0
0.3
0.6
0.0

Wallops AERONET AOD = 0.08

...Current work....

Customize Surface reflectance ratios:

Globally Assumed

Locally Assumed

RGB: 1 Aug 0.47/2.1 ~ 0.45
0.66/2.1 ~ 0.62

0.47/2.1 ~ 0.25
0.66/2.1 ~ 0.50
A new aerosol model
May improve fits !!!

Conclusions

- Aerosols are perfectly sized to interact with solar radiation.
- MODIS has high spectral and spatial resolution in solar bands.
- We exploit aerosol optical spectral dependence to retrieve optical depth and column-averaged size information from MODIS observations.
- Comparisons with ground-based sunphotometer validate the MODIS products, globally.
- Regionally, there is correlation with MODIS column aerosol and surface PM measurements.
- MODIS over land can be improved by customizing surface reflectance relationships, updating the assumed aerosol model dataset, and using a new inversion algorithm.

New land algorithm

| λ(µm) | 0.47 | 0.55 | 0.66 | 1.2 | 1.6 | 2.1 |

Fewer Assumptions!