Spectral single scattering albedo retrievals with MODIS and its applications to direct radiative forcing calculations:

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Atmospheric Absorption by Aerosols

- Heats the atmosphere/Cools the surface
- Changes atmospheric stability
- Affects Cloud Formation and Destruction

• Spectral dependence ↔ Chemical composition, size and mixture
Aerosol refractive index contain important information on aerosol composition and type:

• **Real part**
  - Small variation; difficult to measure
  - Very sensitive to aerosol hydration
    • Aerosols: ~1.55
    • Water: 1.33

• **Imaginary part**
  - Large variations
  - Mainly driven by black carbon, iron oxides, and organic brown carbon
  - Also difficult to measure but can be inverted from absorption efficiency or absorption optical thickness measurements.
Aerosol Spectral Absorption

MODIS Aerosol Bands:

- Dust + Pollution
- Black Carbon in large particles
- Black Carbon in small particles ($\sim 1/\lambda$)
- Organics
- Dust Particles
Aerosol Absorption Efficiency Coarse Particles (Sede Boker)

Abs. Eff. (m²/g)

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14

350 850 1350 1850

Dust

Particles > 2.5µm

470 600 nm wavelength

Aerosol Absorption Efficiency Fine Particles (Sede Boker)

Abs. Eff. (m²/g)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

350 850 1350 1850

Organics

Particles < 2.5µm

470 600 nm wavelength

Thanks to Willy Maenhaut and Derimian Yevgeny for the filters.
Pictures from the Bodele Dust Experiment (BoDEx) 2005

by: Martin Todd, Gill Lizcano (UCL)
Automatic Aerosol Sampling Station for Fennec Experiment in the Sahara June 2011.

- Aerosol filter collection
- Spectral Absorption
- Scattering Coefficient
Dust – Collected at UMBC.

Before a) and after b) sieving: particles < 43mm.

FBAG – Fluidized Bed Aerosol Generator
Using MODIS to retrieve aerosol Absorption:

Images 16 days apart – Same viewing/solar geometry
Critical Reflectance plot for a 20x20km box
Critical Reflectance X Single Scattering Albedo
Single Scattering Albedo retrievals of Dust Aerosols

Kelley Wells, CSU – now at U. Minnesota
Differences with Aeronet SSA

Zhu, Martins, and Remer, 2011
### Average SSA over 60x60km

<table>
<thead>
<tr>
<th>AERONET sites</th>
<th>SSA (at 470 nm)</th>
<th>SSA (at 550 nm)</th>
<th>SSA (at 670 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AERONET</td>
<td>MODIS</td>
<td>AERONET</td>
</tr>
<tr>
<td>Alta Floresta</td>
<td>0.92 ± 0.02</td>
<td>0.92 ± 0.03</td>
<td>0.91 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>(22 cases)</td>
<td>(22 cases)</td>
<td>(18 cases)</td>
</tr>
<tr>
<td>Senanga</td>
<td>0.86 ± 0.01</td>
<td>0.87 ± 0.01</td>
<td>0.85 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>(7 cases)</td>
<td>(7 cases)</td>
<td>(7 cases)</td>
</tr>
<tr>
<td>Mongu</td>
<td>0.88 ± 0.02</td>
<td>0.86 ± 0.02</td>
<td>0.87 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>(14 cases)</td>
<td>(14 cases)</td>
<td>(14 cases)</td>
</tr>
<tr>
<td>Mwinilunga</td>
<td>0.90 ± 0.02</td>
<td>0.86 ± 0.01</td>
<td>0.90 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>(3 cases)</td>
<td>(3 cases)</td>
<td>(3 cases)</td>
</tr>
</tbody>
</table>
Maps – AOD, SSA, AAOD
(on day 252 in 2004)

Zhu, Martins, and Remer, 2011
Maps – AOD, SSA, AAOD
(on day 241 in 2006)

Zhu, Martins, and Remer, 2011
Maps – AOD, SSA, AAOD
(on day 250 in 2000)

Zhu, Martins, and Remer, 2011
Maps – AOD, SSA, AAOD
(on day 254 in 2000)

Zhu, Martins, and Remer, 2011
## Spatial Variability of SSA – (Zhu, Martins, and Remer, JGR 2011)

<table>
<thead>
<tr>
<th>Case Information</th>
<th>AAOD: mean ± standard deviation</th>
<th>Aerosol SSA: mean ± standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>470 nm</td>
<td>550 nm</td>
</tr>
<tr>
<td>latitude = [-15 to -11]; longitude = [21 to 25] over South Africa; on day 254 in 2000</td>
<td>0.13 ± 0.04</td>
<td>0.11 ± 0.04</td>
</tr>
<tr>
<td>latitude = [-18 to -14]; longitude = [22 to 26] over South Africa; on day 250 in 2000</td>
<td>0.18 ± 0.02</td>
<td>0.15 ± 0.02</td>
</tr>
<tr>
<td>latitude = [-12 to -8]; longitude = [-60 to -56] over South America; on day 241 in 2006</td>
<td>0.16 ± 0.04</td>
<td>0.13 ± 0.04</td>
</tr>
<tr>
<td>latitude = [-16 to -12]; longitude = [-60 to -56] over South America; on day 252 in 2004</td>
<td>0.20 ± 0.12</td>
<td>0.14 ± 0.05</td>
</tr>
</tbody>
</table>
Shortwave radiative forcing at TOA from CERES results:
by Elisa T. Sena/University of Sao Paulo

Figure 4: Spatial distribution of the shortwave radiative forcing at the TOA and aerosol optical depth over the Amazon during the biomass burning season of 2005.

Figure 5: Spatial distribution of the shortwave radiative forcing at the TOA and aerosol optical depth over the Amazon during the biomass burning season of 2008.
Main Missing piece for Aerosol Forcing Calculations (after SSA): Spectral Surface Albedo/BRDF properties

• Use MODIS surface BRDF product to calculate surface albedo
• Produce surface albedo (from 0.3 to 2.5 um continuously) by interpolating albedo product in MODIS 7 channels (0.47, 0.55, 0.65, 0.86, 1.24, 1.63, and 2.11 um)
• Combine MODIS Aerosol forcing with CERES results
Spatial Variation of Surface Albedo
Typical Vegetation Surface Albedo
three missing features based on linear interpolation data from MODIS 7 channels
Three Missing Features

![Graph showing vegetation surface albedo from SBDART and surface albedo at MODIS channels across wavelengths from 0.3 to 2.5 micrometers.](graph.png)
Impact in TOA Flux

Error for Flux at TOA
~1.3 W/m²

Error for Flux at TOA
~4.1 W/m²
Thank you.
Explanation – Flux Difference at TOA
Defining Surface Albedo for Forcing Calculations: work in progress