Aerosol Loading and Optical Properties during the May 2003 SGP ARM Aerosol IOP

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Why are aerosols so important?

(IPCC, 2001)
ARM Aerosol IOP 2003

- May 5 – May 31 at the Southern Great Plains (SGP) ARM site in north central Oklahoma.
ARM Aerosol IOP 2003

May 5 – May 31 at the Southern Great Plains (SGP) ARM site in north central Oklahoma.

Enhanced ground based measurements
- Optical properties (e.g. scattering, absorption, AOD)
- Ozone and condensation particle concentrations
- Particle chemical composition

CIRPAS Twin Otter aircraft conducted 16 flights over 15 days totaling 60.6 flight hours.
- In situ optical properties
- In situ particle size and CCN concentrations
- In situ vertical profiles of aerosol properties and WV
Aerosol Optical Properties Calculations

- Used Mie code developed by Michael Mishchenko at the NASA Goddard Institute for Space Studies, New York.

- Inputs
  - Distribution type
  - Particle size range
  - Wavelength
  - Refractive index

- Outputs
  - Single scattering albedo
  - Asymmetry parameter
  - Extinction cross section
Refractive index 1.56 + 0.005i (Russell et al., 1997)

Refractive index 1.56 + 0.025i (Wong and Li, 2002)
Aerosol Optical Depth

\[ t = \int (C_{\text{ext}} \times N) \, dz \]  
(Liou, 1992)

- \( C_{\text{ext}} = \) average extinction cross section per particle
- \( N = \) particle density (# / m³)

\[ \frac{dN}{d\log r} = A \, r^{\frac{(1-3b)}{b}} \exp(- \frac{r}{ab}) \]
where \( 0 < b < 0.5 \)  
(Mishchenko et al., 1999)

- \( A = \) constant
- \( r = \) mean radius
- \( a = \) coefficient

0-6km AOD for MRI = .005 at \( \lambda = .55\mu m \)

| t  | 6.0 km | 5.5 km | 5.0 km | 4.5 km | 4.0 km | 3.5 km | 3.0 km | 2.5 km | 2.0 km | 1.5 km | 1.0 km | 0.5 km | 0.0 km |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| .012 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .018 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .189 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .060 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .074 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .076 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .086 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .115 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .119 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .185 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .282 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .340 |  |  |  |  |  |  |  |  |  |  |  |  |  |
Column Radiative Forcing

\[ \Delta F = -\frac{1}{2}F_t T^2(1-A_c)(1-R_s)^2 \beta \delta a \]  
(Charlson et al., 1992)

- \( F_t \) = global mean TOA radiative flux
- \( T \) = fraction of incident light transmitted by atm. Above aerosol layer
- \( A_c \) = fractional cloud cover
- \( R_s \) = mean albedo of underlying surface
- \( \beta \) = fraction of radiation scattered upward by aerosol
- \( \delta a \) = mean optical depth of the aerosol

\[ \beta = \frac{1}{2}(1 - g) \]  
(Wiscombe and Grams, 1976)

- \( g \) = scattering asymmetry parameter
### Column Radiative Forcing

**For MRI = .005 with β = .191**

<table>
<thead>
<tr>
<th>Albedo</th>
<th>AOD</th>
<th>$\Delta F$ (w/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.3</td>
<td>-8.16</td>
</tr>
<tr>
<td>0.4</td>
<td>0.5</td>
<td>-13.61</td>
</tr>
<tr>
<td>0.4</td>
<td>0.8</td>
<td>-21.77</td>
</tr>
<tr>
<td>0.4</td>
<td>1.2</td>
<td>-32.65</td>
</tr>
<tr>
<td>0.4</td>
<td>1.5</td>
<td>-40.81</td>
</tr>
</tbody>
</table>

**For MRI = .025 with β = .136**

<table>
<thead>
<tr>
<th>Albedo</th>
<th>AOD</th>
<th>$\Delta F$ (w/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>0.3</td>
<td>-3.63</td>
</tr>
<tr>
<td>0.6</td>
<td>0.5</td>
<td>-6.05</td>
</tr>
<tr>
<td>0.6</td>
<td>0.8</td>
<td>-9.67</td>
</tr>
<tr>
<td>0.6</td>
<td>1.2</td>
<td>-14.51</td>
</tr>
<tr>
<td>0.6</td>
<td>1.5</td>
<td>-18.14</td>
</tr>
</tbody>
</table>
Conclusions

- ARM aerosol IOPs are important in helping scientists improve climate models by increasing the process scale understanding of the aerosols and their impact on climate.
- Aerosol chemical (e.g. sulfate, black carbon) and physical properties (e.g. shape, age) are important as shown in the tables.
- The radiative forcing calculations we did indicate the importance of atmospheric aerosols on the radiative balance. For example the radiative forcing calculated is in the range of -2 to -10 w/m², the same order of magnitude as CO2 and other trace gas positive feedbacks.
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