Satellite Data and Model Integration of Global Distribution of Aerosols to Estimate the Aerosol Radiative Effect

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Motivation & Objective

- IPCC report summarizes that the uncertainty for the aerosol direct forcing is about a factor of 2-3, based largely on model simulations.

- In recent years, a great deal of effort has gone into improving measurements and data sets.

- It is feasible to shift the estimates of direct effect from largely model-based to increasingly measurement-based.

- Observations can also be used to improve and constrain model simulations through synthesis and integration.
Integrated Study of Global Aerosols and Direct Effect

Optimum Interpolation (OI)
\[ \sigma^2 = \varepsilon^2 + (f)^2 \]

AERONET
MODIS (Remer)
CERES (Loeb)

MISR

GOCART

Radiative Transfer Model

Aerosol Direct Radiative Effect (clear-sky)

Inter-comparisons

MODIS surface albedo
Data and Model

**MODIS**

- $\pm 0.03 \pm 0.05$ (Ocean)
- $\pm 0.05 \pm 0.20$ (Land), gaps over deserts

**MISR**

- $+0.038$ (Ocean)
- $\pm 0.20$ or $\pm 0.05$ (Land)

**GOCART:** Goddard Global Ozone Chemistry Aerosol Radiation & Transport

- Sulfate, OC, BC, dust, Sea-salt
- driven by the assimilated meteorology
- 30 layers, $2.5^\circ\times2^\circ$ [1.25$^\circ\times1^\circ$ ongoing]

- $\pm 0.01 \pm 0.46$ (Ocean), $\pm 0.04 \pm 0.31$ (Land)

$\Rightarrow$ MO_MI_GO
Annual ave. AOT, 2001

60°S ~ 60°N

<table>
<thead>
<tr>
<th>Model</th>
<th>AOT</th>
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<tbody>
<tr>
<td>MODIS</td>
<td>0.188</td>
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<tr>
<td>MISR</td>
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<td>MO_MI.GO</td>
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<tr>
<td>GOCART</td>
<td>0.134</td>
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Before Integration  After Integration

Angstrom exponent < 1.5

Comparisons with AERONET measurements
Clear-sky Aerosol Direct Effect

GOCART

(c) \(DF_{TOA}\)

-4.1 W/m²

(d) \(DF_{SPC}\)

-7.8 W/m²

\[\Delta = -0.8 \text{ W/m}^2 \quad (20\%)\]

\[\Delta = -1.5 \text{ W/m}^2 \quad (20\%)\]

Annual Average, 2001
Comparisons with AERONET

* Integration increases correlation;
* Integration overall brings the direct effect estimates closer to AERONET measurements;
* Significant low biases. Part of them could result from mismatching between points and 2.5°x2° grids.

$r = 0.54$  
$r = 0.39$  
$r = 0.67$  
$r = 0.44$
AOD < 0.4

TOA

\[ r = 0.68 \]

\[ r = 0.56 \]

Surface

\[ r = 0.69 \]

\[ r = 0.52 \]
Seasonal averages over 13 zones (Land & Ocean separately)

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<th>60°N</th>
<th>EQ.</th>
<th>60°S</th>
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Temperature range: 0.0 to 1.0
13 oceanic zones, seasonal averages of TOA aerosol effect

CERES flux + MODIS aerosol: Loeb & Manalo-Smith, 2005

$r = 0.92, \quad B=0.92\pm 0.17$

$r = 0.83, \quad B=0.74\pm 0.23$
13 oceanic zones, seasonal averages of TOA aerosol effect

MODIS AOT + MODIS aerosol models: Remer & Kaufman, 2005
Integrating MODIS (ocean) and MISR (land) measurements of optical depth into GOCART simulations increases the GOCART clear-sky direct effect estimate by ~20%.

The integration can improve the agreement with measurement-based estimates of aerosol direct effect, including AERONET, MODIS, and CERES.