The Role of Aerosol Absorption in Driving Solar Dimming over East Asia

Geeta G. Persad  
(gpersad@princeton.edu)

Yi Ming, and V. Ramaswamy

Princeton University, Dept. of AOS  
Geophysical Fluid Dynamics Laboratory/NOAA
Outline

What is the role of aerosol absorption in driving clear-sky dimming over East Asia & via what mechanisms is it achieved?

- Motivation: atmospheric heating combined with surface dimming can have unique regional climate impacts

- Experiment Design: hierarchy of AGCM simulations and standalone radiative transfer calculations

- Results and Conclusions

Increased aerosol absorption contributes as much as 1/2 of the clear-sky dimming over East Asia, but via very different mechanisms in different models.
Reduced solar radiation over Asia attributed to increased aerosol concentrations

- Reduced surface solar radiation seen under both all-sky and clear-sky conditions over Asia (e.g. Wild, 2009; 2012)
- Increased aerosol concentrations over Asia are the primary explanation for reduced clear-sky surface solar radiation (e.g. Streets et al. 2006; 2009)

(Tang et al., 2011)
Dimming via aerosol scattering vs. absorption

Global Direct Aerosol Forcing
1990s-preindustrial (W/m2)

TOA  -0.5 to 0.2

Atmosphere  +2 to +4

Surface  -2 to -4

- Dimming via absorption implies surface cooling and atmospheric heating
- Hydrological cycle impacts of surface/atmosphere dipole (e.g. Ramanathan et al., 2001)
- Cloud and convective impacts of atmospheric heating (e.g. Koch and Del Genio, 2010)
- Little work has been done to quantify the contribution of absorption to dimming

(Ramanathan et al., 2001)
Experimental Design

- Two generations of GFDL Atmospheric General Circulation Model (AM2.1 and AM3)
  - Historical integrations and attribution runs
  - Analyze clear-sky surface solar radiation (SSR) trend over Eastern China from 1960 to mid-2000s
- Standalone Radiative Transfer Calculations
  - 1990 and 1970 aerosol burdens
  - Perturbation experiments
    - switch aerosol mixing state
    - disable hygroscopic growth
AM2.1 and AM3 aerosol treatments differ greatly

**AM2.1 (CMIP3)**
- Prescribed Aerosols
  
  *Using MOZART run with emissions from Olivier et al. (1996) via Horowitz et al. (2003)*

- External Mixing

**AM3 (CMIP5)**
- Interactive Aerosols
  
  *Emissions from Lamarque et al. (2010)*

- Internal Mixing of Sulfate and Black Carbon
Both models capture clear-sky dimming trend

\[
\begin{align*}
\text{Trends} & \quad \text{AM2.1: } -0.47 \pm 0.02 \quad [\text{W/m}^2/\text{yr}] \\
& \quad \text{AM3: } -0.30 \pm 0.02
\end{align*}
\]

(Allen et al., 2013)

(Persad et al., 2013, in prep)
Models see nearly identical trend in absorption

Both models: Absorption trend = \(~0.16\) [W/m²/yr]

- Absorption trend explains 1/3 of AM2.1’s dimming trend and 1/2 of AM3’s dimming trend.

(Persad et al., 2013, in prep)
Cancellation of effects between mixing state and aerosol amount

Change in column burden over East China from 1970 to 1990 ($10^{-6}$ kg/m$^2$)

<table>
<thead>
<tr>
<th></th>
<th>AM2.1</th>
<th>AM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfate</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>0.9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Change in absorption from 1970 to 1990 for AM3 aerosols (W/m$^2$)

(Persad et al., 2013, in prep)
Cancellation of effects between mixing state and aerosol amount: Normalized Absorption

\[
\text{Normalized Abs.} = \frac{\Delta \text{Abs}_{\text{aero}} - \Delta \text{Abs}_{\text{no\-aero}}}{\Delta \text{BC column burden}}
\]

- Normalize change in absorption between 1990 and 1970 due to aerosols by the absorbing aerosol column burden
  - Calculate for each mixing state and aerosol burden

(Persad et al., 2013, in prep)
Summary and Conclusions

• Systematically quantify the contribution of absorption to dimming and identify driving aerosol mechanisms

• Both aerosol treatments are capable of capturing the observed trend of clear-sky dimming over East Asia

• Dimming is driven strongly by absorption in both models, but via very different mechanisms
  - AM2.1: Large change in aerosol column burden
  - AM3: Strong absorption per unit aerosol due to internal mixing

• Greater observational constraints of aerosol mechanisms will be needed to project future regional climate response to East Asian dimming
Acknowledgements

- Thanks to Paul Ginoux and Stephen Fueglistaler for feedback on early stages of this work.
- Geeta G. Persad is supported by the National Science Foundation Graduate Research Fellowship under grant DGE 1148900.

Manuscript in internal review for submission to JGR-Atmospheres

Corresponding Author: G. G. Persad
gpersad@princeton.edu
Aerosols drive clear-sky dimming in both models

**AM2.1 (CMIP3)**

**AM3 (CMIP5)**

No significant trend in WMGHG or Natural only runs in either model.

(Persad et al., 2013, in prep)