Atmospheric Chemistry & Transport: Estimating SLCF Distributions and Contributions

Greg Carmichael, University of Iowa

Many Current Studies (e.g.)

LRTAP - Hemispheric Transport of Air Pollutants
Royal Society - Ground-level ozone in the 21st century: future trends, impacts and policy implications
NAS - Global Sources of Local Pollution
UNEP - Opportunities to Limit Near-Term Climate Change
IGAC/SPARC - Bounding the role of black carbon in climate

Major Atmospheric Transport Pathways and Processes Impacting SLCF

NAS Global Sources of Local Pollution, 2010
Models Play a Critical Role in Linking Emissions to SLCF Distributions and Subsequent Radiative/Climate Effects

Models try to represent our present understanding of the processes at play

Δ metric / Δ E

Uncertainties

Increasing

Significant
Large Scale Comprehensive Field Experiments Like NASA Intex B Experiment Explore Our Understanding of Atmospheric Processes

Adhikary et al., ACP, 2010
Observations at Mt. Bachelor Provide Valuable Insights Into The Variability In Atmospheric Composition in the Western US.

Significant variability in the vertical -- challenges to models and observing systems!

Adhikary et al., ACP 2010
Transport and Deposition Processes in The Himalaya Region Have Important Implications for Water and Food Security

ABC Nepal Climate Observatory (NCO-P)
- Remote site in Himalayan region
- 5079 m asl
- 27.9 N, 86.7 E
- Complex topography

S. Fuzzi and team
Beijing Plume Influence at Cheju

Cheju ABC Plume-Asian Monsoon Experiment (CAPMEX) – NSF/KOSEF Providing Insights Into The Impacts of Aerosols

Ramanathan, Yoon, et al.,

Emission Inventories
Natural – Anthropogenic Meteorological Fields
4-D Aerosol Distribution
Aerosol Optical Depth
Direct Radiative Effect
Direct Climate Forcing
Climate Response

Scattering

Simulated (L - dry 0%, U - amb)
Simulated (RH = 40%)
Observed

Absorption

Simulated (L - 5 m²g⁻¹, U - 20 m²g⁻¹)
Simulated (9.8 m²g⁻¹)
Observed

August September

Scattering Coefficient at 532 nm [Mm⁻¹]

Absorption Coefficient at 532 nm [Mm⁻¹]

Data: Flowers et al.
Quantifying Aerosol Radiative Forcing and the Role of Anthropogenic Components Remains a Challenge

Chung, C. E., et al., ACPD, 2009

Strong atmospheric heating due to absorbing aerosol implications for processes impacting weather and climate

Chung, C. E., et al., ACPD, 2009
Incorporation of Aerosol Into Weather Prediction Will Provide Further Insights Into Processes

Case24 = Intex-B emission (2006)
Case22 = reduced Olympic emission (BJ+SD)
Time period Aug 2008

Beijing Olympics WRF-Chem Sensitivities
Moving Forward We Need More Analysis Related to Source Sectors & Fuels and Policy Relevant Scenarios

Asia emissions analyzed by sector
Sector Focus Places Greater Demand on Emissions, Models and Observing Systems

Average contribution (%) from Asian anthropogenic and open burning emissions to simulated BC and SO$_4$ at Trinidad Head (THD), Mt. Bachelor (MBO) and ABC Pyramid site (PYR) during INTEX-B (April 15-May15 2006)

Average contribution (%) from Asian anthropogenic and open burning emissions to simulated BC and SO$_4$ at Trinidad Head (THD) and Mt. Bachelor (MBO) during INTEX-B (April 15-May15 2006)
Due to the Complexity and Uncertainties in Calculating the Sources, Formation, Transport and Removal of Aerosols in the Atmosphere, a Closer Integration of Observations and Models is Needed.
Due to the Complexity and Uncertainties in Calculating the Sources, Formation, Transport and Removal of Aerosols in the Atmosphere, a Closer Integration of Observations and Model Needed

Uno et al., Nature Geo, 2009
Fig. 1. Radiative forcing due to perpetual constant year 2000 emissions grouped by sector at (a) 2020 (b) 2100 showing the contribution from each species. The net sum of total radiative forcing is indicated by the title of each bar. A positive RF means that removal will result in climate cooling and vice versa.
Summary of Major Sources of Uncertainty in the Calculations

**Multiplicative Uncertainties**

<table>
<thead>
<tr>
<th></th>
<th>Emissions</th>
<th>Wet removal</th>
<th>Vertical Transport</th>
<th>Chemical Formation</th>
<th>Total Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>nss SO4</td>
<td>1.3</td>
<td>1.3</td>
<td>1.5</td>
<td>1.3</td>
<td>1.8</td>
</tr>
<tr>
<td>BC</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
<td>--</td>
<td>3.9</td>
</tr>
<tr>
<td>OC</td>
<td>3.5</td>
<td>2</td>
<td>1.5</td>
<td>3</td>
<td>6.4</td>
</tr>
<tr>
<td>Dust</td>
<td>5</td>
<td>2</td>
<td>1.5</td>
<td>--</td>
<td>6.0</td>
</tr>
<tr>
<td>Sea Salt</td>
<td>5</td>
<td>1.3</td>
<td>1.5</td>
<td>--</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Note: for analysis of specific points some of these terms are larger…