Aerosol Radiative Forcing

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Key Question

• How are emissions affecting the atmospheric aerosol concentrations?
• The answer is important for evaluating the impacts of emissions from past to the present, and into the future

Perspectives from diagnoses of Observations and Model Simulations
Critical Factors
Relative importance of different factors on aerosol distributions and forcing

- Emissions (hydrophobic vs. hydrophilic)
- Anthropogenic and natural aero
- Microphysics and chemistry (dependent on aerosol type)
- Transformation (removal efficiency of various aerosols)
- Transport away from source regions (horizontally, vertically)
- Effect of relative humidity (especially on cloud-scales)
- Precipitation events (intensity and frequency)
- clouds
Figure 2. Comparison of modeled (3 years of data) and measured black carbon at Sable Island (60°W, 43.9°N). The mean and geometric deviation of the observations is shown, while, for the model, the values for each of the 3 years of simulation are plotted.

Figure 3. Same as Figure 2 except at Bondville (88.4°W, 30.1°N).
Radiative forcing (W m\(^{-2}\)) for standard case July
Surface radiative forcing (W m\(^{-2}\)) for standard case July

Global forcing = -0.20  NH forcing = -0.37  SH forcing = -0.03
Table 4. Sensitivity of atmospheric burden of the black carbon aerosol to variation of various parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Burden (Tg)</th>
<th>Lifetime (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>0.060</td>
<td>4.29</td>
</tr>
<tr>
<td>Transformation Time Halved</td>
<td>0.045</td>
<td>3.22</td>
</tr>
<tr>
<td>Transformation Time Doubled</td>
<td>0.064</td>
<td>4.58</td>
</tr>
<tr>
<td>90% hydrophobic emission</td>
<td>0.066</td>
<td>4.72</td>
</tr>
<tr>
<td>100% hydrophobic emission</td>
<td>0.069</td>
<td>4.94</td>
</tr>
<tr>
<td>100% soluble aerosol</td>
<td>0.033</td>
<td>2.36</td>
</tr>
<tr>
<td>Wet deposition rate halved</td>
<td>0.079</td>
<td>5.65</td>
</tr>
<tr>
<td>No wet deposition allowed</td>
<td>1.593</td>
<td>114.0</td>
</tr>
</tbody>
</table>
NACIP Objectives

(i) To measure the sources, distribution and properties of aerosols (particularly soot) and their influence on cloud formation, rainfall and radiation budget globally on a region-by-region basis;

(ii) to model the emissions, transport and transformation processes in the atmosphere that govern aerosol distributions and forcings, including realistic representations of aerosols in climate models based on observations;

(iii) and to quantify the relative importance of aerosols and greenhouse gases in global warming, including regional climate impacts.
Model Simulations
3D GCMs; Cloud resolving models; parcel models; assimilation models

- Process-level understanding
- Simulate and understand the observed variability (concentrations, optics, radiation)
- Climate variations of the past two decades as a test for models?
- Links between aerosol forcing, climate response and air quality
  - Surface temperature
  - Hydrologic cycle
  - Surface heat and water budget
  - Visibility, health
- Evolution: past to present to future
Climate Impacts

- Global, annual-mean surface temperature
- Going further…..
- Regional-scale changes
- Changes in hydrologic cycle, surface heat and water budgets
The global mean radiative forcing of the climate system for the year 2000, relative to 1750.
Atmospheric Aerosol Climate Forcing in Reflected Solar Radiation: A Comparison of Observations and GCM Simulations

Spatial signatures and magnitude of clear-sky aerosol radiative forcing identified through satellite/model comparison. Sea-salt is a leading contributor.
Figure 5: The global climate of the 21st century will depend on natural changes and the response of the climate system to human activities. Climate models project the response of many climate variables — such as increases in global surface temperature and sea level — to various scenarios of greenhouse gas and other human-related emissions. (a) shows the CO$_2$ emissions of the six illustrative SRES scenarios, which are summarised in the box below, along with IS92a for comparison purposes with the SAR. (b) shows anthropogenic SO$_2$ emissions. (c) shows