Air Pollution Impacts on Climate
- Regional Climate Effect of Ozone and Black Carbon Studied by Observation and a Chemical-Climate Model -

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* Work done at FRCGC (Y. Kanaya, K. Sudo and other science team members)
Ozone and Black Carbon

They are two major air pollutants with positive radiative forcing.

Therefore,

They should be targeting species for mid-term mitigation policy for global warming.

In this study,

More straightforward “direct” effect on global/ regional climate change by these species have been evaluated in order to contribute to co-benefit/co-control policy between air pollution and global warming.
1. Evaluation of regional forcing by observation in Central Eastern China

2. Evaluation of global forcing by chemical-climate model, CHASER-CCSR/NIES/FRCGC.
Selected Three Mountain Sites in the Central Eastern China for the Study of Regional Air Pollution

Overlapping with the Tropospheric NO₂ Column by OMI (NASA Data)
Observation Sites in the Central Eastern China

華山 (Mt. Hua)
泰山 (Mt. Tai)
黄山 (Mt. Huang)

1836 m
1538 m
2063 m
Monthly Variation of Surface Ozone Concentration at the Three Mountains (2004-2006)
Observed PM$_1$ black carbon concentration at Mt. Tai, Mt. Huang and Kyrgyz mountain.
### Estimate of TOA Radiative Forcing in Global Average and in Central Eastern China

<table>
<thead>
<tr>
<th>Species</th>
<th>Sensitivity</th>
<th>Global</th>
<th>Central East China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Concentration (Present)</td>
<td>Concentration (Preindustrial)</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>0.01677 W m(^{-2}) ppm(^{-1})</td>
<td>379 ppm</td>
<td>280 ppm</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>0.00045 W m(^{-2}) ppb(^{-1})</td>
<td>1774 ppb</td>
<td>715 ppb</td>
</tr>
<tr>
<td>O(_3)</td>
<td>0.032 DU(^{-1})</td>
<td>40 DU</td>
<td>30 DU</td>
</tr>
<tr>
<td>BC</td>
<td>1.25 W mg(^{-1})</td>
<td>0.4 mg m(^{-2})</td>
<td>0.2 mg m(^{-2})</td>
</tr>
</tbody>
</table>

* Estimated value
Setup of Model Experiment for Radiative Forcing and Climate Sensitivity of Ozone and Black carbon

Base Model: CHASER/SPRINTARS + CCSR/NIES/FRCGC GCM
Species: Gas Phase Chemistry + SO$_4^{2-}$, BC, OC, SD, SS
Spatial resolution: T42 (2.8° mesh)
Emissions: HYDE/EDGAR + Forest/Agriculture Waste Burning
Model Experiments: Equilibrated Climate Response Runs from Pre-industrial (~ 1850) to Present (~ 2000)
LLGHG = CO$_2$ + CH$_4$ + N$_2$O + CFC
Instantaneous Radiative Forcing of Trop. O₃ since Pre-industrial

LT: Trop. O₃ Increase
→ +0.49 W m⁻²
(LLGHGs
→ +2.38 W m⁻²)

LTm: Trop. O₃ increase (assuming longitudinally uniform increase)

LT-LTm

Effect of longitudinal ununiform distribution
Impact of Tropospheric Ozone Increase on Equilibrated Surface (2m) Temperature
### Relative Importance of LLGHG and Tropospheric O$_3$ on Equilibrated Surface Temperature

<table>
<thead>
<tr>
<th></th>
<th>Global</th>
<th>NH</th>
<th>SH</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLGHGs</td>
<td>+2.23 $^\circ$C</td>
<td>+1.78 $^\circ$C</td>
<td>+2.78 $^\circ$C</td>
</tr>
<tr>
<td>Tropospheric O$_3$</td>
<td>+0.28 $^\circ$C</td>
<td>+0.31 $^\circ$C</td>
<td>+0.25 $^\circ$C</td>
</tr>
<tr>
<td>Trop.O$_3$/ LLGHGs</td>
<td>12.6 (%)</td>
<td>17.4 (%)</td>
<td>9.0 (%)</td>
</tr>
</tbody>
</table>

**Regionally over 40 %**
Comparison between calculated (SPRINTARS) and Observed BC and OC Concentrations at Mt. Tai
Annual Mean Radiative Forcing and Temperature Increase by BC

<table>
<thead>
<tr>
<th>Species</th>
<th>Global RF (W m⁻²)</th>
<th>Global T (°C)</th>
<th>NH RF (W m⁻²)</th>
<th>NH T (°C)</th>
<th>SH RF (W m⁻²)</th>
<th>SH T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>0.52</td>
<td>0.49</td>
<td>0.75</td>
<td>0.51</td>
<td>0.30</td>
<td>0.44</td>
</tr>
<tr>
<td>O₃</td>
<td>0.49</td>
<td>0.28</td>
<td>0.59</td>
<td>0.31</td>
<td>0.38</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Note: Pre-industrial BC is set to zero, which would give overestimation.
Comparison of $O_3$ and BC for Spatial Distribution of Radiative Forcing and Temperature Increase in Summer

**O$_3$: Radiative Forcing**

**BC: Radiative Forcing**

**O$_3$: Temperature Increase**

**BC: Temperature Increase**
Summary

1. Global and annual mean radiative forcing of trop. O$_3$ and BC is evaluated to be 0.49 and 0.52 W m$^{-2}$, respectively.

2. Global annual mean temperature increase by trop. O$_3$ and BC is evaluated to be 0.28 and 0.49 °C, respectively.

3. Substantial difference in spatial distributions of radiative forcing and temperature increase can be seen between O$_3$ and BC.

   e.g. NH/SH contrast is more distinct for BC than O$_3$. 