Long-Term Trend of Particle Number Concentrations in the United States and Implications

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PM2.5 over US has been decreasing.

What about particle numbers?

**GEOS-Chem**

V10.1, with APM

$2^\circ \times 2.5^\circ$, driven by MERRA2 Simulation period: Originally 2000-2017, recently extended to 1989-2018 (30 years).
Particle formation and evolution processes treated in APM
Both ammonia and ions can significantly enhance new particle formation in the atmosphere.

H$_2$SO$_4$-H$_2$O-NH$_3$ ternary ion-mediated nucleation (TIMN)

Yu et al., ACP, 2018

References: CLOUD data and CLOUDpara (Dunne et al., 2016) ACDC (McGrath et al., 2012; Kürten et al., 2016)
Association between Each Inter-Quartile Range (IQR) Increase in UFP or PM2.5 and the Excess Risk (%) for Respiratory Diseases

<table>
<thead>
<tr>
<th>Lag case</th>
<th>UFP IQR (#/cm³)</th>
<th>Excess risk (95 CI%)</th>
<th>PM2.5 IQR (µg/m³)</th>
<th>Excess risk (95 CI%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0</td>
<td>272,235</td>
<td>3480</td>
<td>10.7</td>
<td>0.7 (-0.1, 1.4)</td>
</tr>
<tr>
<td>0-1</td>
<td>272,187</td>
<td>3250</td>
<td>10.1</td>
<td>1.1 (0.3, 1.9)</td>
</tr>
<tr>
<td>0-2</td>
<td>272,130</td>
<td>3063.3</td>
<td>9.4</td>
<td>1.3 (0.4, 2.2)</td>
</tr>
<tr>
<td>0-3</td>
<td>272,079</td>
<td>2910</td>
<td>9.1</td>
<td>1.6 (0.6, 2.5)</td>
</tr>
<tr>
<td>0-4</td>
<td>272,035</td>
<td>2786</td>
<td>8.8</td>
<td>1.9 (0.9, 2.9)</td>
</tr>
<tr>
<td>0-5</td>
<td>271,988</td>
<td>2659.3</td>
<td>8.6</td>
<td>2.0 (0.9, 3.0)</td>
</tr>
<tr>
<td>0-6</td>
<td>271,944</td>
<td>2587.1</td>
<td>8.5</td>
<td>2.2 (1.1, 3.3)</td>
</tr>
</tbody>
</table>
Aerosol Direct Radiative Forcing (DRF)

Long term trends of observed and modeled AOD at GSFC AERONET site

\[ y = -0.0079x + 16.038 \]

\[ y = -0.0071x + 14.368 \]

\[ R^2 = 0.85 \]
Aerosol Direct Radiative Forcing (DRF)

2001

Aerosol First indirect Radiative Forcing (FIRF)

2016
Summary

We employ GEOS-Chem-APM to investigate the long term variations and trends of particle number concentrations over US. Particle number concentrations over US decreases in the past two decades decreases but at a magnitude less than the reduction in \( SO_2 \) emission, partially as a result of compensation effect of \( NH_3 \) increase in new particle formation.

Our preliminary study indicates similar magnitude of the impacts of ultrafine particle number concentrations on respiratory diseases to those dues to PM2.5.

In the last two decades, AOD in northeast US decreased by a factor of \( \sim 2 \). Similar magnitude of decrease in aerosol DRF but much less change in aerosol first IRF in the region.
Seasonal variation of mass-weighted mean diameter of secondary particles.
GSFC, Surface Layer, $R_{AOD-CCN} = 0.03$, $R_{AOD-CDN} = -0.18$, $R_{CCN-CDN}=0.72$

GSFC, 1 km, $R_{AOD-CCN} = 0.51$, $R_{AOD-CDN} = 0.13$, $R_{CCN-CDN}=0.57$

GSFC, 2 km, $R_{AOD-CCN} = 0.67$, $R_{AOD-CDN} = 0.4$, $R_{CCN-CDN}=0.72$