Increasing surface ozone concentrations in the background atmosphere of Southern China, 1994–2007

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Outline

- Introduction
- Data and methodologies
- Results and discussion
- Conclusions
Motivation

• Importance of $O_3$: air quality, atmospheric oxidizing capability, and climate change.

• Processes controlling surface $O_3$: stratospheric intrusion, photochemical formation, deposition, etc.

• Sharp rise in anthropogenic emissions: rapid urbanization and industrial development.

• Very limited knowledge of the long-term ozone trends in China: lack of long-term continuous data.
Objectives

• To determine the long-term change and seasonal variations in ozone at non-urban site in Southern China.

• To identify major types of air-mass groups that contributed to the surface ozone change.

• To assess the impact of background air on the ozone changes in urban area of Hong Kong.
Data and Methodology

Fig. 1. Map showing the location of the Hok Tsui station in Hong Kong and a weather station at Waglan Island (WGL) and an urban air quality monitoring station at Central/Western (CW)
Data and Methodology (cont.)

• **Surface observational data** (1994-2007):
  – CO and O₃ at the Hok Tsui (non-urban).
  – O₃ and NOₓ at Central/Western (CW) site (urban).

• **Satellite measurements**:
Data and Methodology (cont.)

• Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model v4.8.
  – Cluster analysis.

• Trend Analysis
  – Linear regression to data and de-seasonalized data.
Results and discussion
long-term change

Fig. 2. Monthly mean ozone mixing ratios and the linear fit line at Hok Tsui, Hong Kong, during 1994-2007.
Seasonal variation of ozone

Fig. 3. Whisker plot of the seasonal variation of ozone at Hok Tsui during the 1994–2007 period.
## Rates of change in seasonal mean

Table 1. Rate of change in seasonally averaged ozone by two methods.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rate (ppbv/yr)</td>
<td>rate (ppbv/yr)</td>
</tr>
<tr>
<td>Spring</td>
<td>0.41</td>
<td>0.84</td>
</tr>
<tr>
<td>Summer</td>
<td>0.52</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Autumn</strong></td>
<td><strong>0.68</strong></td>
<td><strong>1.02</strong></td>
</tr>
<tr>
<td>Winter</td>
<td>0.50</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Fig. 4. Four major types of 10-day backward trajectories at Hok Tsui: East China, Central China+PRD, Aged continental, and Marine. [6-box indicated regions: (1) NCP: North China Plain, (2) YRD: Yangtze River Delta, (3) PRD: Pearl River Delta, (4) Kr-Jp: Korea and Japan, (5) TW: Taiwan, (6) SA: Southeast Asia].
Characteristics of different air-mass groups

Table 2. Pooled means and standard deviations of ozone and CO in the four air-mass groups.

<table>
<thead>
<tr>
<th>Air mass type</th>
<th>O₃(ppbv)</th>
<th>CO(ppbv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East China*</td>
<td>48(14)</td>
<td>357(141)</td>
</tr>
<tr>
<td>Central China + PRD</td>
<td>42(20)</td>
<td>488(204)</td>
</tr>
<tr>
<td>Aged continental*</td>
<td>38(16)</td>
<td>235(88)</td>
</tr>
<tr>
<td>Marine*</td>
<td>22(10)</td>
<td>128(48)</td>
</tr>
</tbody>
</table>

* With the wind/CO filter (see text for detail).

Table 3. Rate of change for yearly pooled average of ozone in the four air-mass groups.

<table>
<thead>
<tr>
<th>Air mass type</th>
<th>Linear regression</th>
<th>Comparing the difference between 1994–2000 and 2001–2007 (ppbv/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rate (ppbv/yr)</td>
<td>p value</td>
</tr>
<tr>
<td>East China*</td>
<td>0.64</td>
<td>0.08</td>
</tr>
<tr>
<td>Central China + PRD</td>
<td>0.67</td>
<td>0.21</td>
</tr>
<tr>
<td>Aged Continental*</td>
<td>0.45</td>
<td>0.21</td>
</tr>
<tr>
<td>Marine*</td>
<td>0.29</td>
<td>0.27</td>
</tr>
</tbody>
</table>

* With the wind/CO filter

** Significant at 95% confidence level
Change of tropospheric NO$_2$ column

Fig.5. Monthly mean tropospheric NO$_2$ column concentration retrieved from GOME (March 1996–June 2002) and SCIAMACHY (July 2002–November 2007) for NCP.
Long-term change of CO

Fig. 6. Monthly mean CO mixing ratios and the linear fit line at Hok Tsui, Hong Kong, during 1994-2007.
Total O$_3$ and impact of background air

- **Definition and calculation of total ozone:**
  \[ \text{O}_3 + \text{NO} \rightarrow \text{NO}_2 + \text{O}_2 \]
  \[ [\text{Total O}_3] = [\text{O}_3 + \text{NO}_2]_{\text{observed}} - [\text{NO}_2] \text{ directly emitted} \]
  Total ozone change rate \( V_t \):
  \[ V_t = V_{[\text{O}_3 + \text{NO}_2]} - V_{[\text{NO}_2]} = V_{[\text{O}_3 + \text{NO}_2]} - C \ast V_{[\text{NO}_x]} \]
  \[ = 0.72 \text{ (ppbv/yr)} \]
  C: NO$_2$/NO$_x$ emission ratio, 0.041 (ppbv/ppbv).

- **The impact of background air on ozone in urban Hong Kong:**
  \[ V_h / V_t = 0.58 / 0.72 = 81\% \]
  \( V_h \): The rate of increase in ozone at Hok Tsui station
Long-term changes of $O_3$, $NO_2 + O_3$, and $NO_x$ at an urban site

Fig. 7. Monthly mean $O_3$ mixing ratios at Hok Tsui, $O_3$ and $O_3+NO_2$ at an urban site (Central/Western) in Hong Kong; $NO_x$ at Central/Western in Hong Kong (lower panel).
Conclusions

• The trend of ozone changes at Hok Tsui station
  – Overall change: increased at a rate of 0.58 ppbv/yr.
  – Seasonal changes: minimum in summer, highest in autumn.

• Major types of air-mass groups that contributed to the surface ozone increase
  – Marine, East China, Central China + PRD and Aged continental groups.
  – Mainly affected by continental sources.

• The main factor affecting the increase of ozone in background air
  – Large increase in the emissions of ozone precursors over the eastern coastal regions of China.

• The impact of background air on ozone in urban Hong Kong
  – Contributed 81% to the increase in “total ozone” in the urban of Hong Kong.
Thank you for your attention!

Questions?