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Atmospheric Chemistry and Physics

Atmos. Chem. Phys., 9, 6217–6227, 2009 www.atmos-chem-phys.net/9/6217/2009/

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

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October 27, 2017

# 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

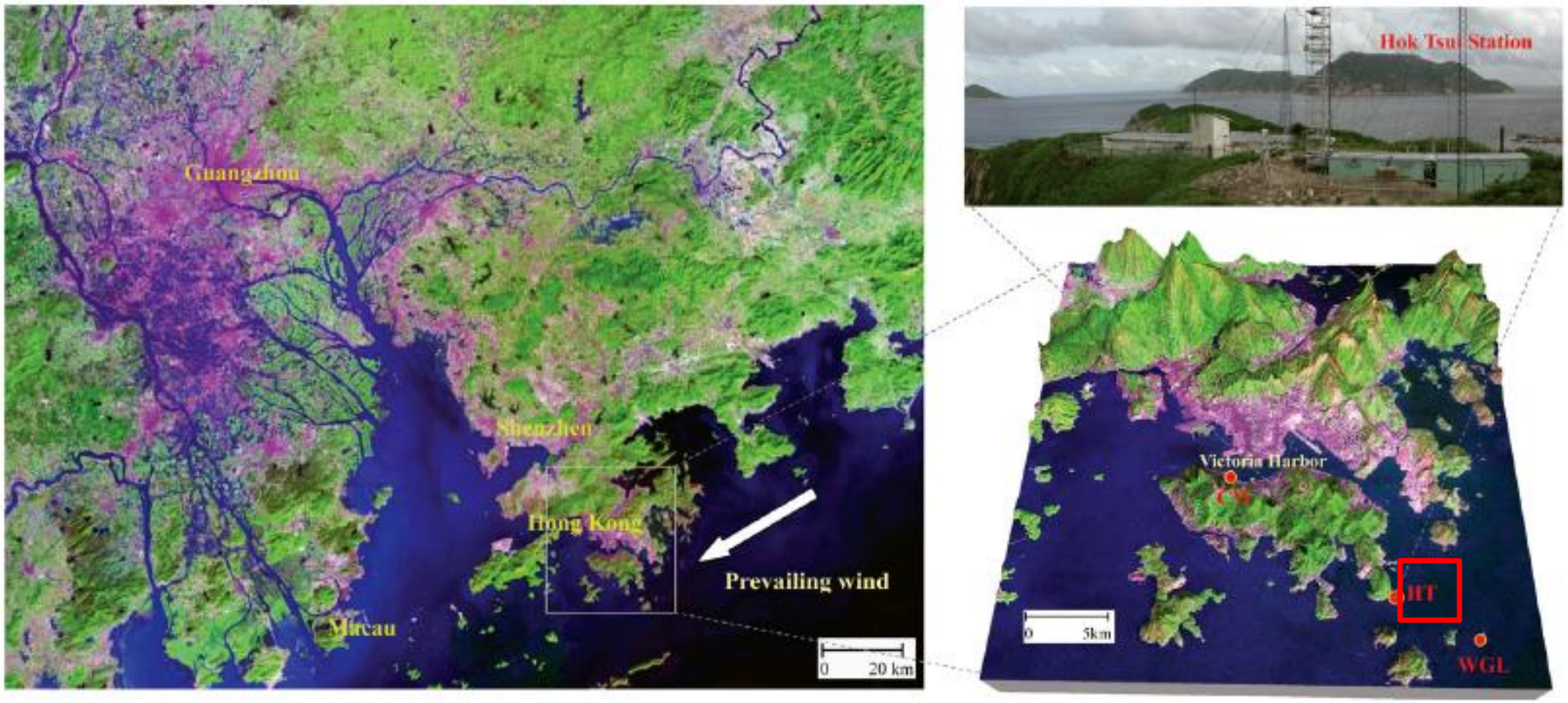


Fig.1. Map showing the location of the Hok Tsui station in Hong Kong and a weather station at Waglan Island (WGL) and an urban air quality monitoring station at Central/Western (CW)

# Data and Methodology (cont.)

- Surface observational data (1994-2007):
  - CO and $O_3$ at the Hok Tsui (non-urban).
  - $O_3$ and $NO_x$ at Central/Western (CW) site（urban）.
- Satellite measurements:
  - GOME (Global Ozone Monitoring Experiment) : 1995–2002.
  - SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography): 2003 onwards.

# 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.
  - Yearly change and difference between two time periods (1994-2000,2001-2007).

# Results and discussion
## long-term change

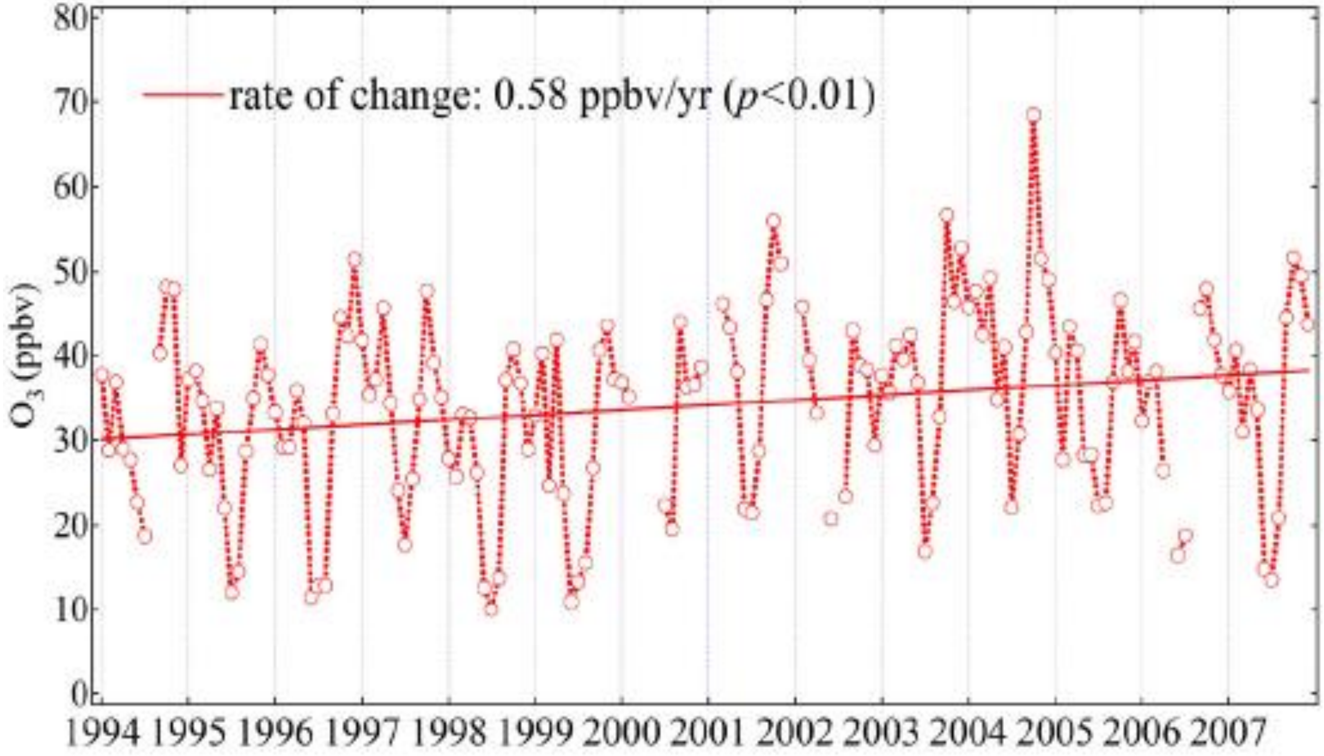


Fig. 2. Monthly mean ozone mixing ratios and the linear fit line at Hok Tsui, Hong Kong, during 1994-2007.

# Seasonal variation of ozone

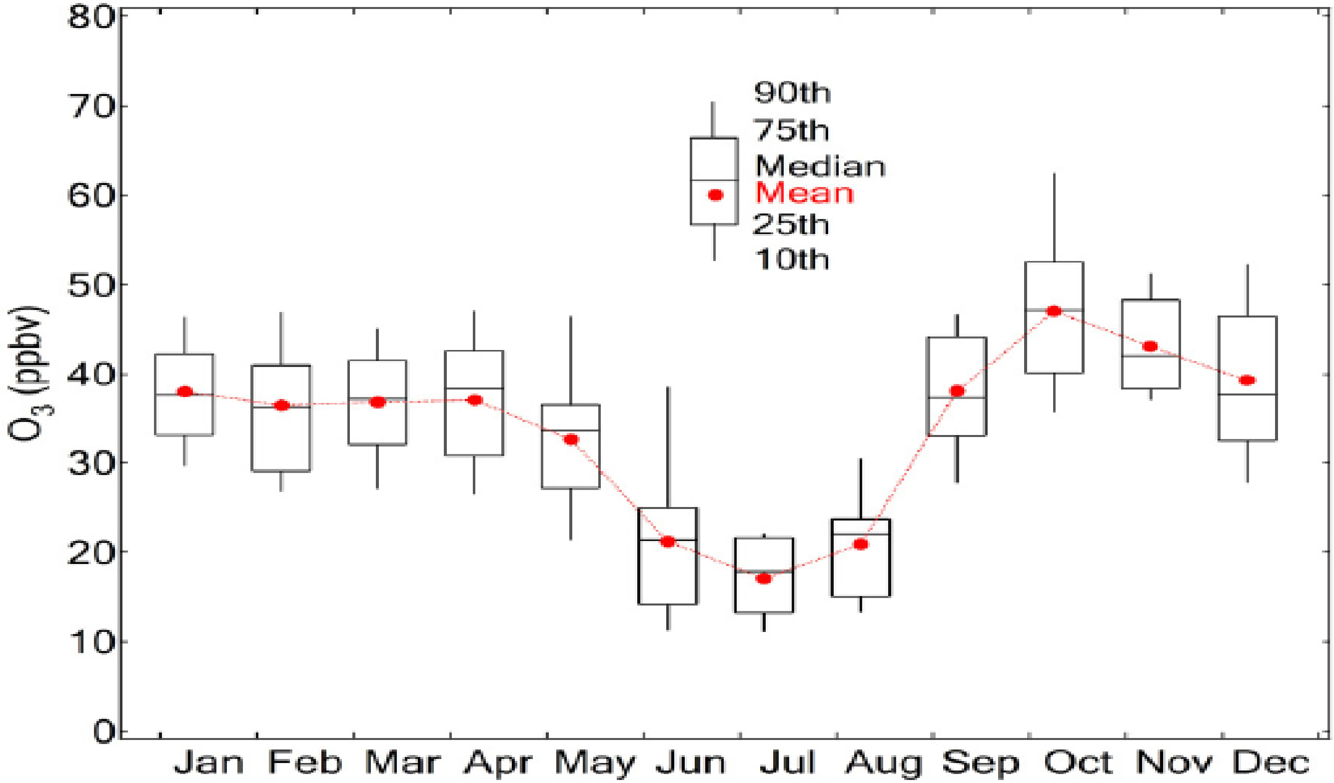


Fig. 3. Whisker plot of the seasonal variation of ozone at Hok Tsui during the 1994–2007 period.

# Rates of change in seasonal mean

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

| | Linear regression | | Comparing the difference between 1994–2000 and 2001–2007 | |
|---|---|---|---|---|
| Season | rate (ppbv/yr) | *p* value | rate (ppbv/yr) | confidence level |
| Spring | 0.41 | 0.18 | 0.84 | 99% |
| Summer | 0.52 | 0.15 | 0.99 | 99% |
| Autumn | 0.68 | 0.07 | 1.02 | 99% |
| Winter | 0.50 | 0.12 | 0.73 | 95% |

# Types of air-mass groups

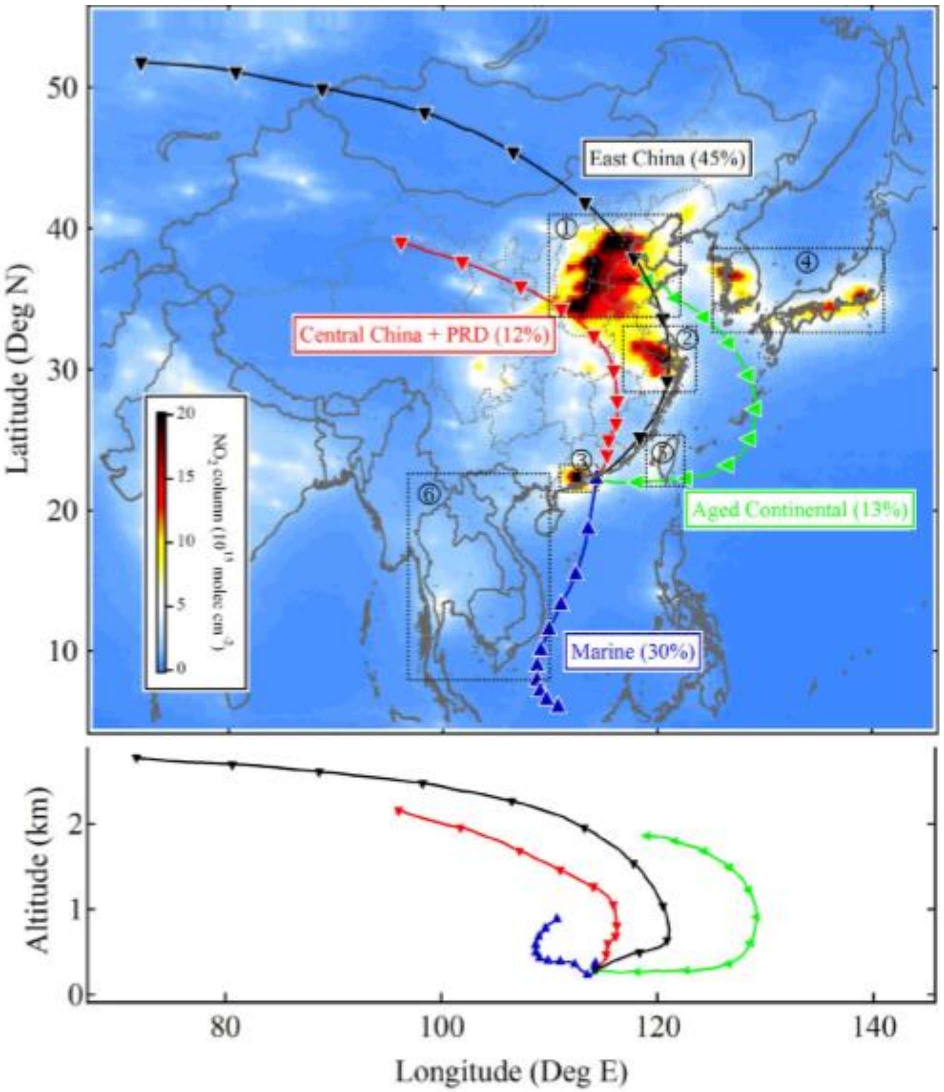


Fig. 4. Four major types of 10-day backward trajectories at Hok Tsui: East China, Central China+PRD, Aged continental, and Marine. [6-box indicated regions: (1) NCP: North China Plain, (2) YRD: Yangtze River Delta, (3) PRD: Pearl River Delta, (4) Kr-Jp: Korea and Japan, (5) TW: Taiwan, (6) SA: Southeast Asia].

# Characteristics of different air-mass groups

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

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| Air mass type | $O_3$ (ppbv) | CO(ppbv) |
|---|---|---|
| East China* | 48(14) | 357(141) |
| Central China + PRD | 42(20) | 488(204) |
| Aged continental* | 38(16) | 235(88) |
| Marine* | 22(10) | 128(48) |

* 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.

| Air mass type | Linear regression rate (ppbv/yr) | Linear regression $p$ value | Comparing the difference between 1994–2000 and 2001–2007 (ppbv/yr) |
|---|---|---|---|
| East China* | 0.64 | 0.08 | 0.94** |
| Central China + PRD | 0.67 | 0.21 | 1.20** |
| Aged Continental* | 0.45 | 0.21 | 0.85** |
| Marine* | 0.29 | 0.27 | 0.57 |

* With the wind/CO filter

** Significant at 95% confidence level

# Change of tropospheric $NO_2$ column

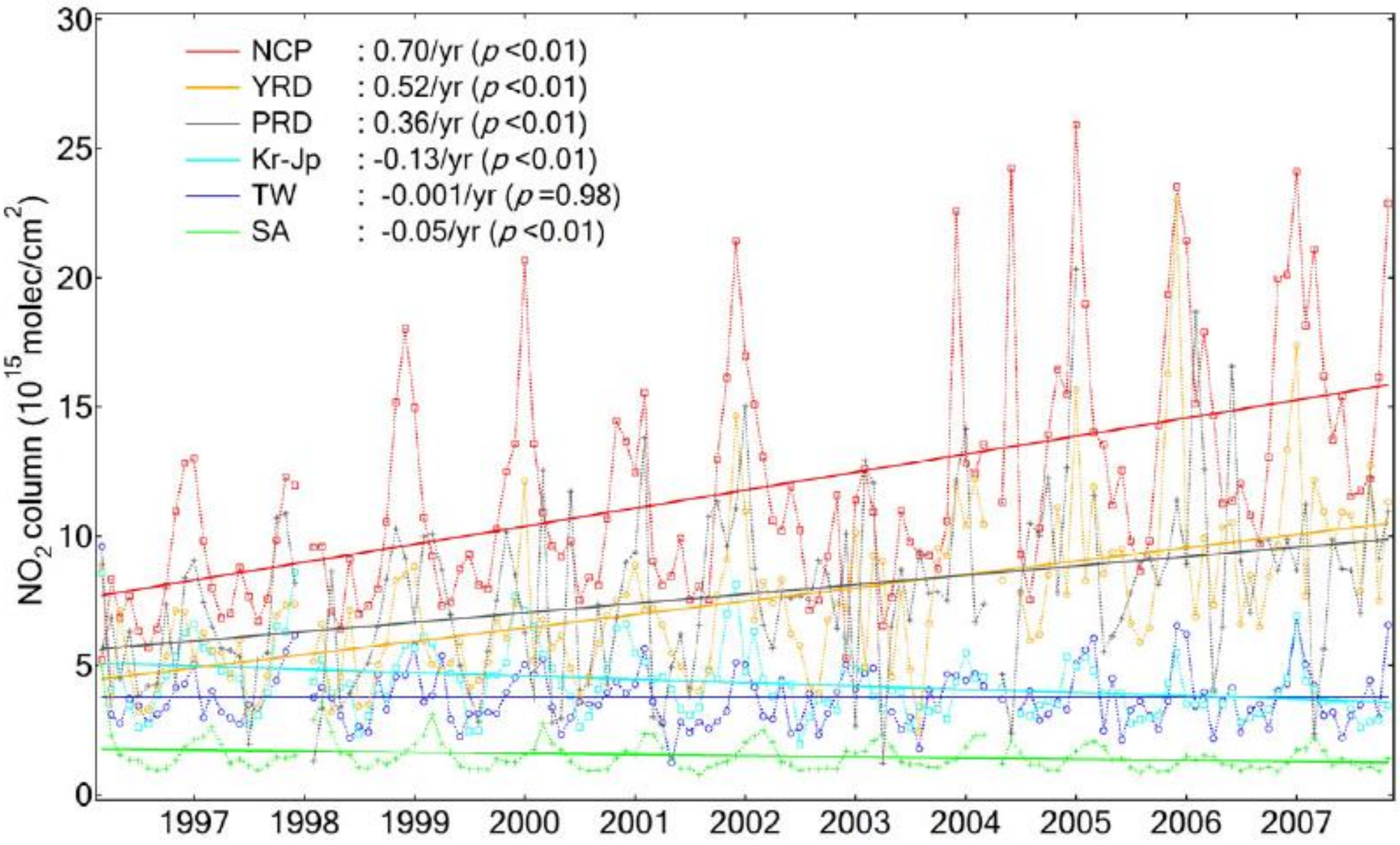


Fig.5. Monthly mean tropospheric $NO_2$ column concentration retrieved from GOME (March 1996–June 2002) and SCIAMACHY (July 2002–November 2007) for NCP.

# Long-term change of CO

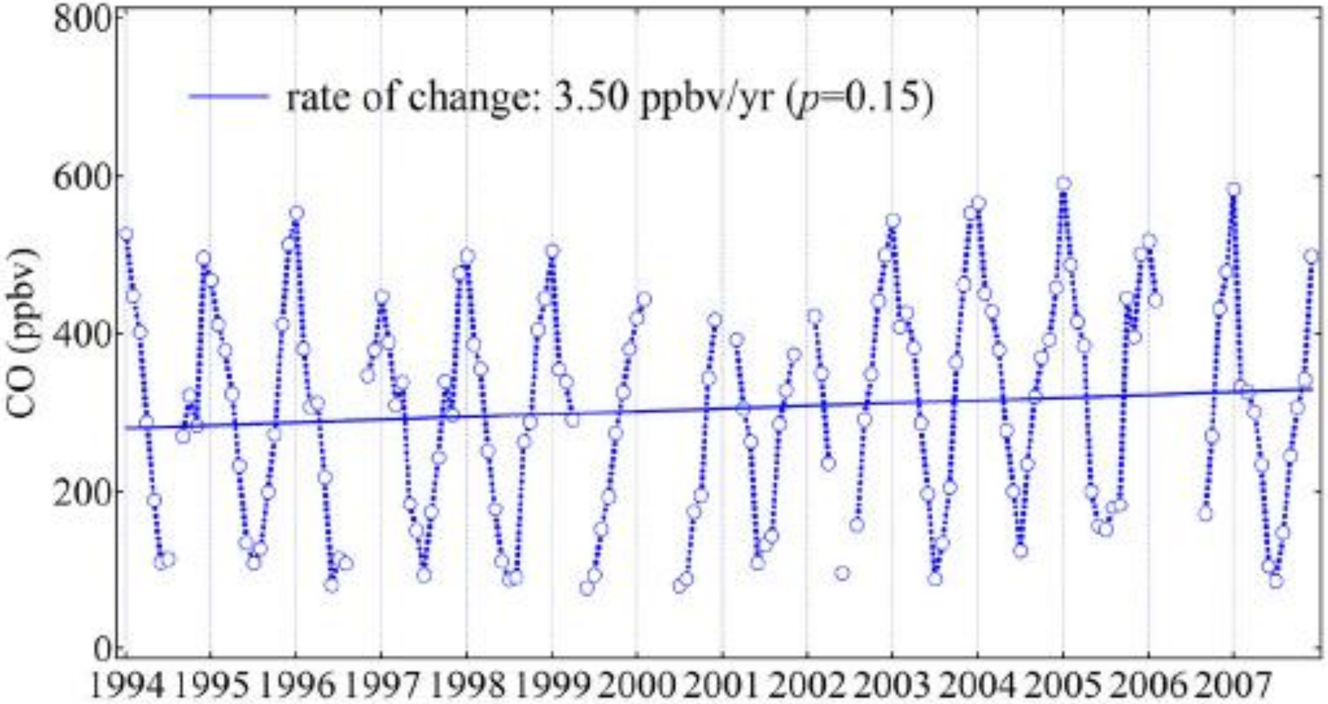


Fig. 6. Monthly mean CO mixing ratios and the linear fit line at Hok Tsui, Hong Kong, during 1994-2007.

# Total $O_3$ and impact of background air

- Definition and calculation of total ozone:

$$O_3 + NO \rightarrow NO_2 + O_2$$

$$[\text{Total } O_3] = [O_3 + NO_2]_{observed} - [NO_2]_{\text{directly emitted}}$$

Total ozone change rate $V_t$ :

$$V_t = V_{[O_3 + NO_2]} - V_{[NO_2]} = V_{[O_3 + NO_2]} - C * V_{[NO_x]}$$
$$= 0.72 \text{（ppbv/yr）}$$

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

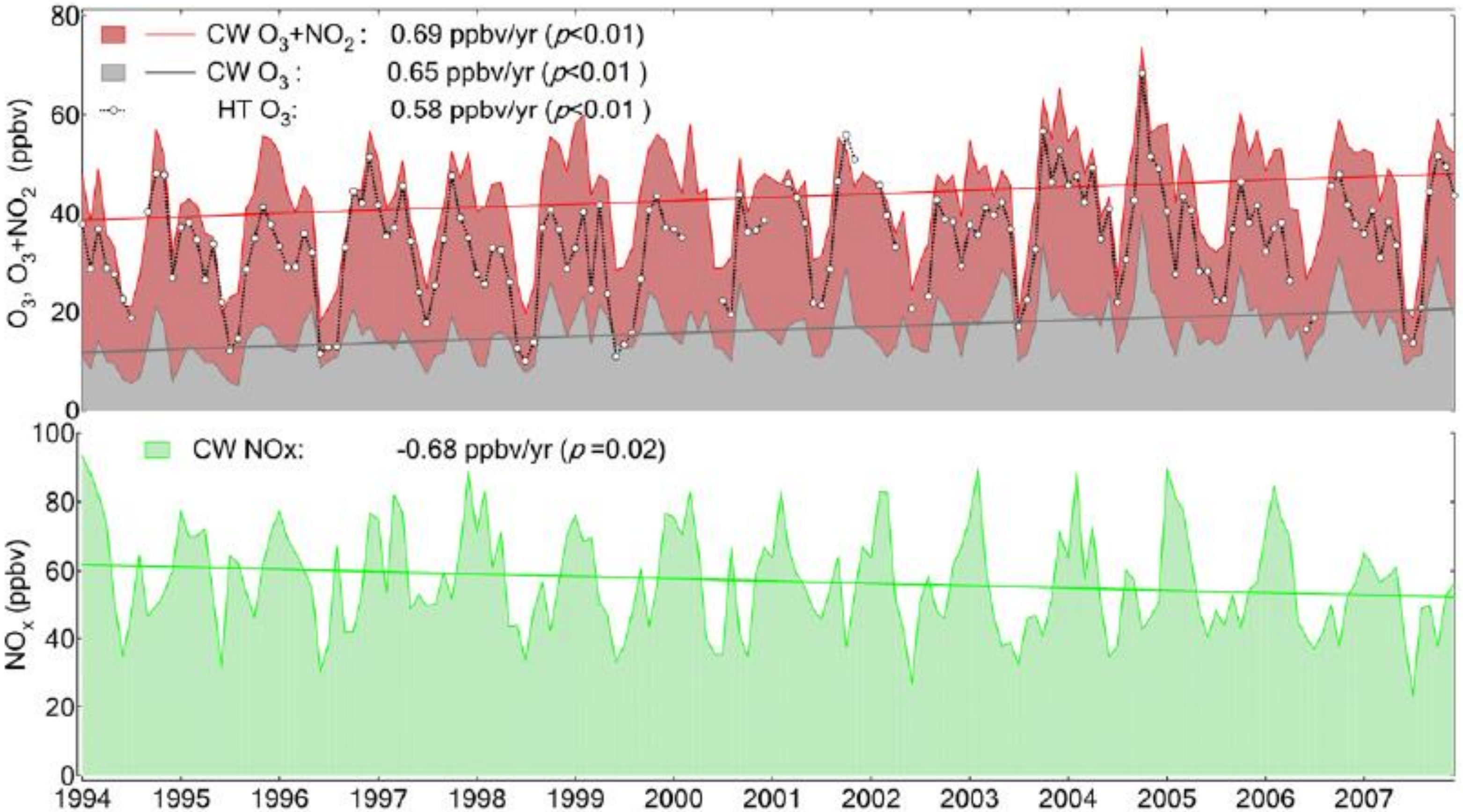


Fig. 7. Monthly mean $O_3$ mixing ratios at Hok Tsui, $O_3$ and $O_3$+$NO_2$ at an urban site (Central/Western) in Hong Kong); $NO_X$ at Central/Western in Hong Kong (lower panel).

# 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 ?