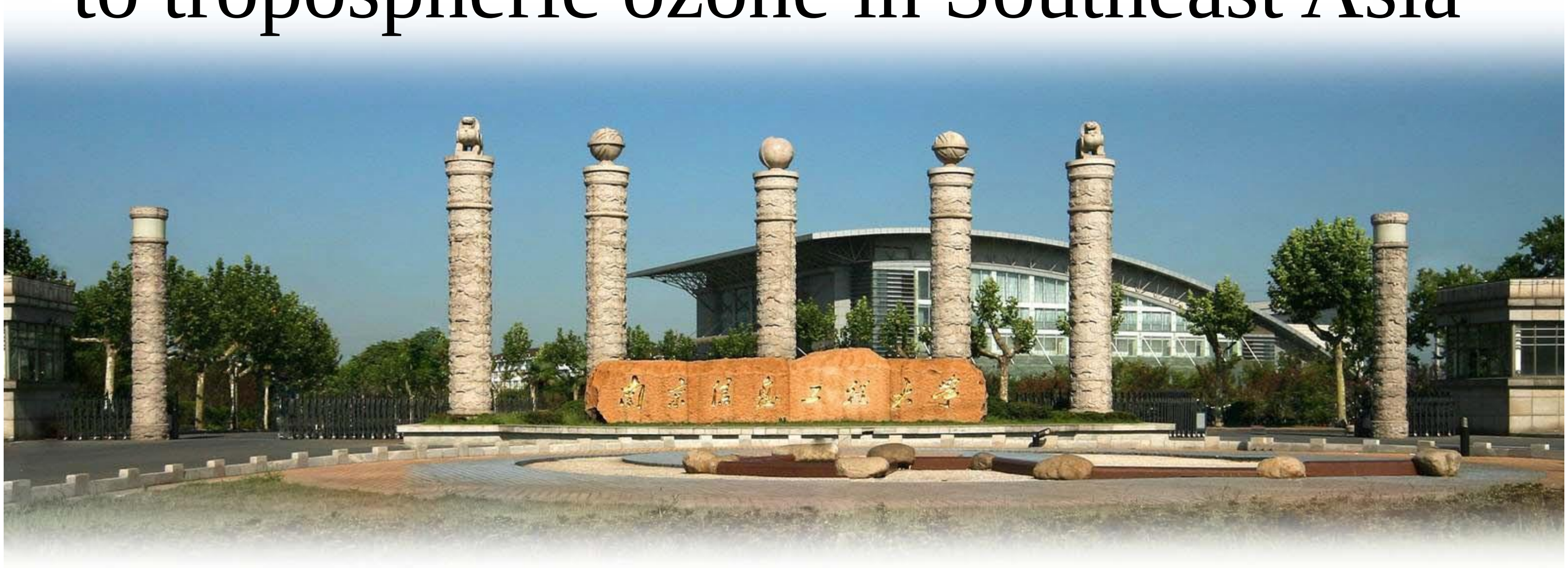
Contributions of biomass burning and stratosphere-troposphere exchange to tropospheric ozone in Southeast Asia



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Outline

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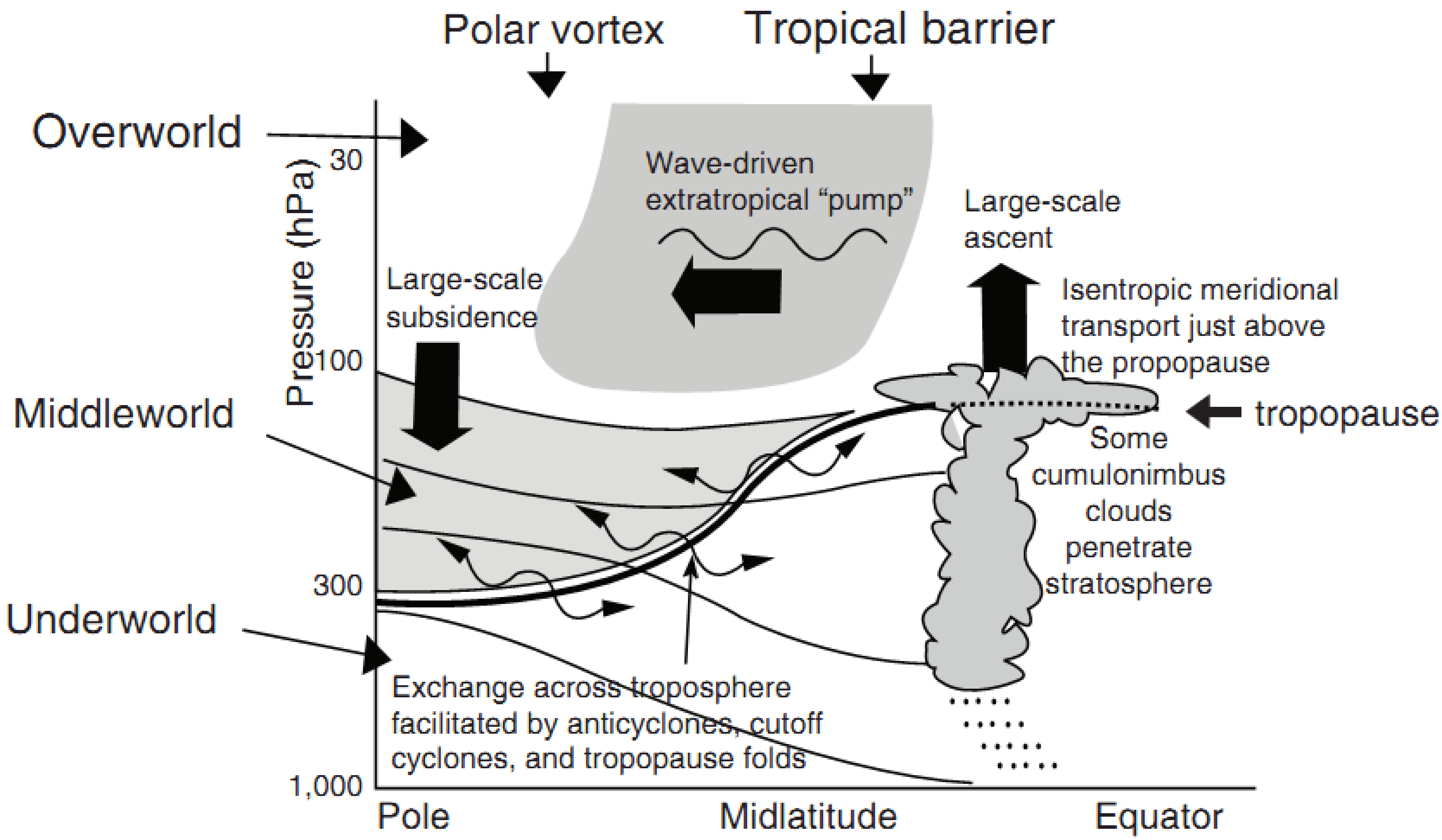
Background

- It is found that in spring profiles sometimes displayed unusually high concentrations in the lower tropospheric layers at around 2.5 ~ 4.5 km. The enhancement in ozone is attributed to downward transport from the stratosphere or photochemical production in the troposphere.
- Biomass burning had been reported to exert important effects on the abundance of trace gases (e.g. ozone) in the atmosphere.
- Tropical Asia is a region with extensive biomass burning events occurred in spring time. The east-central India region and the region covering Thailand, Cambodia, and Vietnam are recognized as the two major areas of biomass burning in India and southeast Asia (Christopher and Kimberly, 1996,1998).

Background (cont.)

- Stratosphere–troposphere exchange (STE) is a part of the general circulation of the atmosphere that transports air and atmospheric constituents across the tropopause.
- Stratosphere–troposphere exchange was first proposed by Brewer (1949) and Dobson (1956) to explain water vapor and ozone measurements.
- The meso-scale STE has direct implications on the distribution of atmospheric ozone, in particular, the decrease of lower stratospheric ozone and the increase of tropospheric ozone (Hartmann et al. 2000).



Schematic representation of stratosphere–troposphere exchange through tropopause (K. Mohanakumar ,2008)

Background (cont.)

- Recognizing the importance of these processes for the climate system, the World Climate Research Programme (WCRP) set up, in 1992, a research project to study Stratospheric Processes and their Role in Climate (SPARC).
- Strong downward fluxes of air mass from the stratosphere appear in eastern Asia Although its area accounts 5.6% of the Northern Hemi sphere (NH) , the net exchange value reaches 29% of the total mass ex change in NH. This means the STE in the eastern Asia is important for t he Northern Hemisphere.(Yang and Lu，2004)

Motivation and objectives

- Motivation
  - In the past, most related studies are limited to examine individual role of biomass burning and STE. Very few studies are focused on their relative contributions during the spring time unusually high ozone events in the lower tropospheric layer over Southeast Asia.
- Objectives
  - What is the relative importance of tropospheric photochemical production and STE during springtime high ozone in the low tropospheric layer?
  - How are their relative contributions changed with different synoptic atterns?
  - How are STE contributions varied with seasons and latitude?

Data and method

- Ozone sounding data (2001-2010?) from WOUDC http://www.woudc.org/index_e.html
- The 10 years (2001-2010) ECMWF data sets

  http://dataportal.ecmwf.int/data/d/interim_full_daily
- Fire counts from ATSR World Fire Atlas

  http://due.esrin.esa.int/wfa/

Methodology

- **Define tropopause height**

- PV method (traditional way)

Dynamic tropopause is used with potential vorticity instead of vertical temperature gradient as the defining variable.The most common ones are that the tropopause lies at the 2 PVU (potential vorticity unit) or 1.5 PVU surface.

- Ozone vertical gradient

The tropopause height is defined as the height where vertical ozone-mixing ratio has a sharp positive vertical gradient at a particular altitude somewhere in the tropopause region. It can be used for defining an ozone tropopause from a single ozone sounding.

Methodology (cont.)

- We use traditional way combined with Hoerling e al.,(1993) produce a “blended” analysis that to analyzed in subtropics tropopause pressures according to

$$P = (W)P_{dynamical} + (1 - W)P_{thermal}$$

Where the weight W are defined by

$$W = A \operatorname{sech}(\varphi) + B\varphi^2 + C.$$

when $\varphi = 28°$, $W=1$; when $\varphi = 13°$, $W = 0$; when $\varphi = 22°$, $W = 0.5$.

Methodology: STE flux of O_3

- Wei's formula to calculate STE flux of ozone

$$F(\rho) = -g^{-1}\left(\frac{DP}{Dt} - \frac{\partial P_{tp}}{\partial t} - V \cdot \nabla P_{tp}\right) = \left(\frac{1}{g}(V \cdot \nabla P)_{tp} - \frac{\omega}{g}\right) + \frac{1}{g}\frac{\partial P_{tp}}{\partial t}$$

ω= DP / Dt vertical velocity

P_{tp}: pressure of the tropopause

- Ozone mixing ratio

$$q_{trop} = \frac{\int_{p_{tropopause\ 3}}^{p_{tropopause}} q(p)\mathrm{d}p}{\int_{p_{tropopause\ 3}}^{p_{tropopause}} \mathrm{d}p}, \quad q_{stra} = \frac{\int_{p_{tropopause}}^{p_{tropopause+3}} q(p)\mathrm{d}p}{\int_{p_{tropopause}}^{p_{tropopause+3}} \mathrm{d}p}$$

$P_{tropopause}$: pressure of the tropopause

$P_{tropopause-n}$ & $P_{tropopouse+n}$: pressure at n km altitude below and n km above the tropopause respectively.

Preliminary results

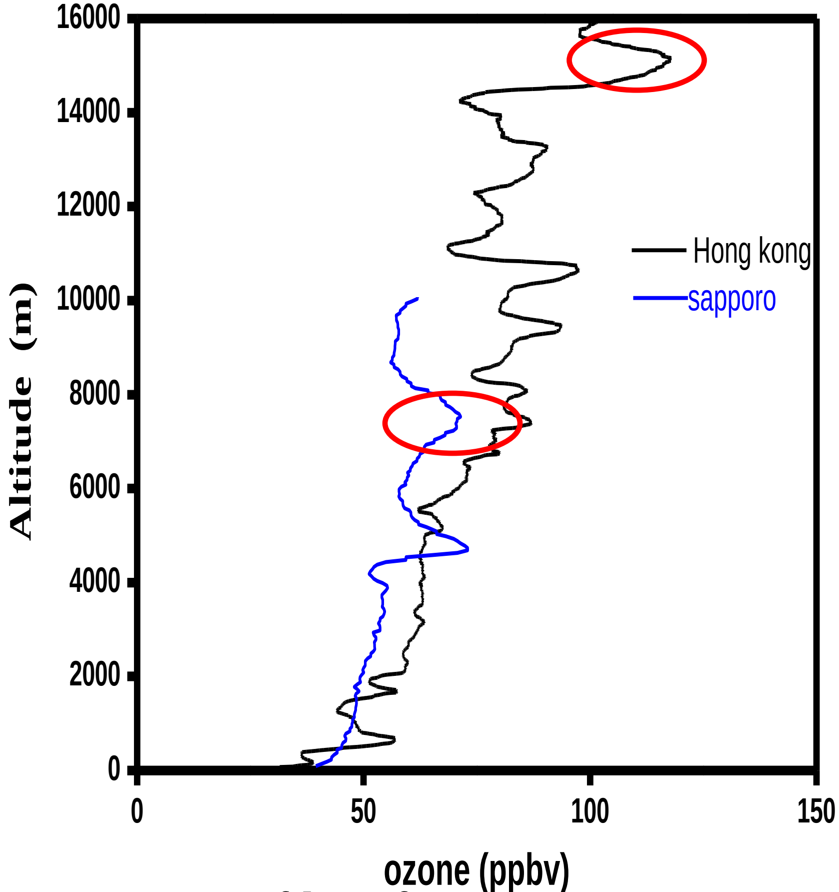


Figure 1 Profiles of ozone mixing ratio at Hong Kong and Sapporo on 7 April 2004

The tropopause of Hong Kong is about 14~16Km, but for Sapporo is around 8~10Km.

Preliminary results

Table 1 Comparison of calculated STE fluxes with other studies' results

Author	Time	Tropopause	Ozone flux ($g.m^{-2}.s^{-1}$)
Spaete et al. （1994）	1day	3PVU	3.5
Lamarque et al. （1994）	4days	2PVU	0.4
Wirth （1995）	3 days	2PVU	3.5
Ebel et al. （1996）	1.96days	3PVU	1.4
Yang 2002）	85hours	3.5PVU	0.49
this study	3days	2PVU&380K	Hong Kong: 1.21 Sapporo: 0.79

Preliminary results

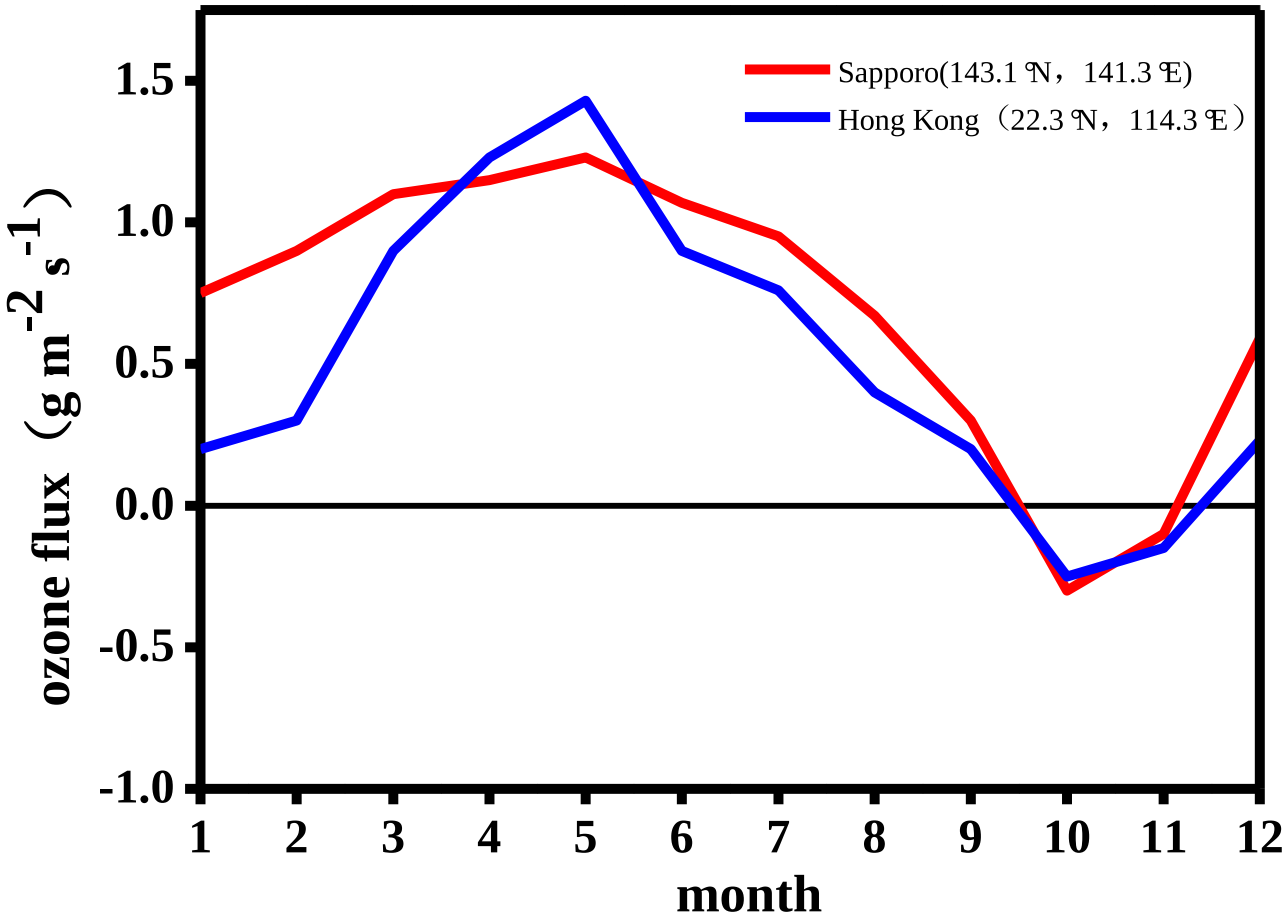


Figure 2 The monthly means of STE ozone fluxes at Hong Kong and Sapporo

Preliminary results

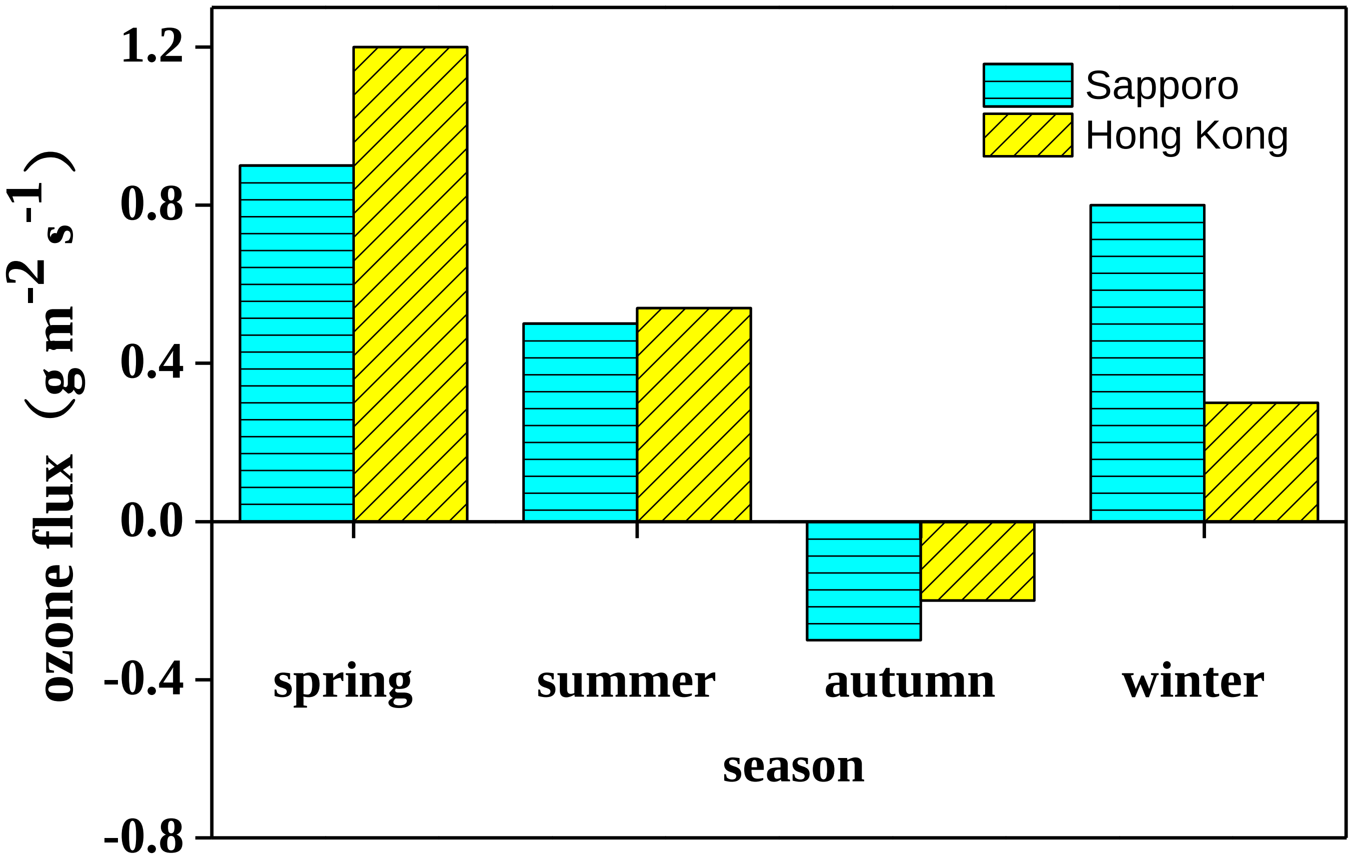


Figure 3 Seasonal means of STE ozone fluxes at Hong Kong and Sapporo

Preliminary results

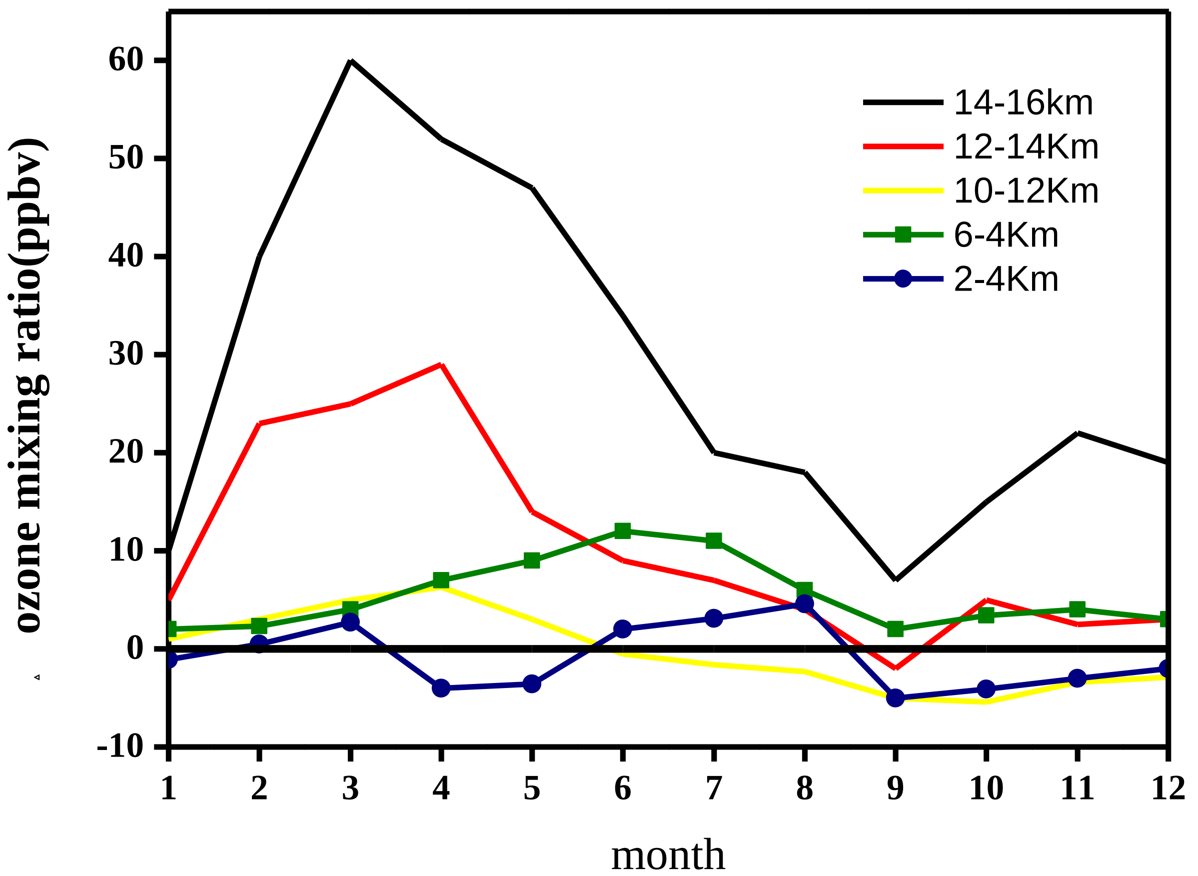


Figure 4 The △O_3 mixing ratio at different heights in Hong Kong

Discussions

- Determination of tropopause height

➢ Tropopause is the transition layer between the troposphere and the stratosphere, where an abrupt change in temperature lapse rate usually occurs. But the tropopause is not a fixed boundary layer.

➢ Tropopause height shows large variations with latitude, season, and even day-to-day.

Discussions (cont.)

Table 2 Comparison of tropopause heights at different regions (K. Mohanakumar,2008)

Features	Tropical tropopause	Midlatitude tropopause	Polar tropopause
Location	Over tropics, between the two subtropical jet streams	Between polar and subtropical jet streams	North of polar jet
Height	∼18 km	∼12 km	6–9 km
Altitude	∼80–100 hPa	∼200 hPa	∼300–400 hPa
Temperature	∼ −80°C	∼ −60°C	∼ −45°C
Potential temperature	∼375–400 K	∼325–340 K	∼300–310 K
Character	Sharply defined, highest and coldest	Higher in summer and lower in winter	Often difficult to identify

Discussions (cont.)

- Calculation of STE ozone fluxes

- ➢ There are many ways to estimate the flux of ozone across the tropopause, for example, by correlation of concentrations of nitrous oxide (N_2O) with O_3 (Murphy and Fahey, 1994) or by correlation of ozone column and PV column (Olsen et al., 2002, 2003), the contour advection technique (Jing et al., 2004), or chemical transport modelling (Crutzen et al., 1999)
- ➢ Wei's formula (four types: Wei's-p, Wei's-z, Wei's-θ, Wei's-pv)

Summary

- Hong Kong and Sapporo both had the max STE ozone fluxes in spring .
- Hong kong`s ozone high event may mainly contribute from stratosphere-troposphere exchange instead of biomass burning .
- In different latitude ,the variation of ozone fluxes are quite different.

On-going work

- Analysing more sites and try to find a better way to define the tropopause.(maybe use modeling data)

- To compare the relative contribution of STE and photochemical production to tropospheric ozone in different seasons and locations.

- To compare the relative roles of STE and photochemical production in the troposphere under different synoptic patterns.


Thank you！