A proposal on study of annual variation in lower/middle tropospheric ozone over East Asia

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Presented to Yale-NUIST Center on Atmospheric Environment

September 9, 2011

Outline

- Introduction of O_3
- Reference review on tropospheric O_3
- Objectives
- Methodology
- Expected Results
- Discussion

Introduction: how ozone is formed?

- A carton shows how O_3 is formed

  http://www.epa.gov/airnow/ozone/o3.html

- Ozone (O_3) is created from Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs) when the favorable meteorological conditions are available. NOx and VOCs come from factories, power plants, mobiles, vegetations etc.

Introduction: Photochemical smog

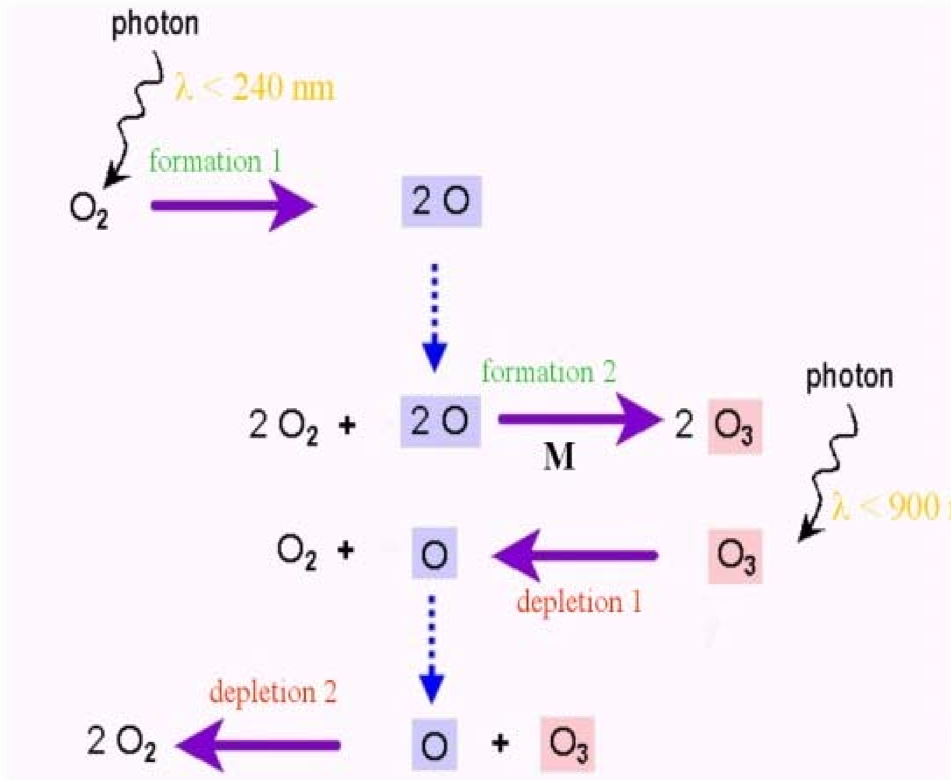
Introduction: O_3 chemistry

- In stratosphere

$O_2 + h\nu \rightarrow 2\ O$ ($\lambda < 240$ nm)

$O + O_2 + M \rightarrow O_3 + M$

$O_3 + O \rightarrow 2\ O_2$



The Chapman cycle

Introduction: O_3 chemistry (cont.)

- **In the polluted air**
  - Nitrogen cycle

    NO_2 + hv -> NO + O (1)

    O + O_2 + M -> O_3 + M (2)

    O_3 + NO -> NO_2 + O_2 (3)

    net: a null cycle
  - Hydrocarbon (RH) cycle

    RH + OH -> H_2O + R (4)

    R + O_2 + M -> RO_2 + M (5)

    RO_2 + NO -> NO_2 + RO (6)

    OH + HCHO -> H_2O + HCO (7)

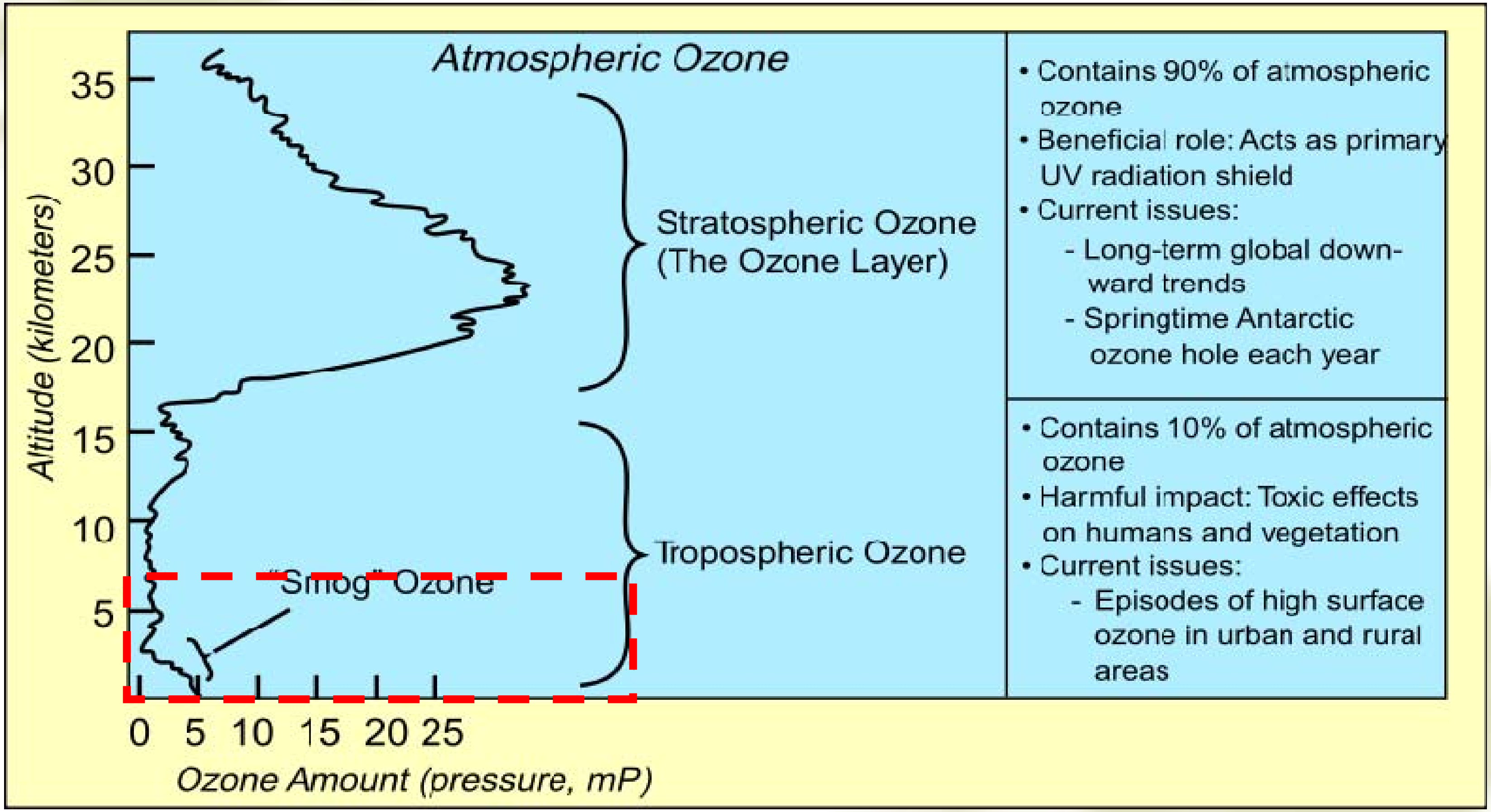
    HCO + O_2 -> HO_2 + CO (8)

    HO_2 + NO -> NO_2 + OH (9)
  - **O_3 is accumulated** when reactions (6) and (9) complete with R(3), i.e., NO_x and VOC (or RH) are available in the atmosphere

Introduction: Is O_3 good or bad?

- Good (stratospheric O_3): to protect life on Earth by absorbing ultraviolet radiation from the sun, particularly UVB radiation that can cause skin cancer and cataracts, damage crops, and destroy some types of marine life
- Bad (high ground-level O_3): has adverse effects on human health, damages ecosystems and reduces crop and forest yields
- O_3: a strong oxidant and has an important implication on global balance of atmospheric chemical species and climate change

Introduction: vertical distribution



Our study will be focused on the lower/middle troposphere (< 5~7 km)

Reference review: tropospheric O_3

Springtime maximum ozone in the lower troposphere

1. L.Y.Chan C.Y.Chan, and H.Y.Liu (GRL,2000) found that biomass burning in Southeast Asia is the main contributor to the enhancement of tropospheric ozone over Hong Kong

2. H. Liu, and D. J. Jacob (JGR, 2003) used a global three-dimensional model and Transport and Chemical Evolution over the Pacific (TRACE-P) aircraft mission satellite data, to study Asian pollution (i.e., CO) outflow to Pacific. They found the major driving processes are frontal lifting, cross-border transport and orographic lifting. But their study was limited to CO, not O_3. (a related study)

Reference review: tropospheric O_3 (cont.)

3. S. J. Oltmans, B. J. Johnson (JGR, 2004) used ozonesonde data to study the variation of tropospheric ozone over the north Pacific, and found a prominent spring maximum throughout the troposphere。They pointed out the enhanced O_3 is closely related to biomass burning.

4. A. J. Ding, T. Wang (ACP,2008) analyzed aircraft data and found that during daytime O_3 has higher daytime concentrations in the lower troposphere, and tropospheric ozone climatology shows a narrow peak in early summer (June) in the lower troposphere and a broad summer maximum in the middle troposphere.

Reference review: tropospheric O_3 (cont.)

5. J. H.KIM and Hyunjin LEE (AMS, 2010) found that the springtime tropospheric O3 maximum over Northeast Asia was caused by photochemical production.

6. D. Shen and T. Wang (TAS ,2011) used satellites data to study the trend of tropospheric ozone variation in recent 30 years over China and found ozone was enhanced by the pollutant of biomass burning.

Reference review: tropospheric O_3 (cont.)

7. X. Xu, W. Lin (ACCR,2010) analyzed satellite data during 1979-2005. and found a slight increase of TOR in summer and a decrease in other seasons, and insignificant overall trend over China.

8. Y. Li, C. Zhao (JAMS, 2007) analyzed 20-year satellite data to study the distribution and seasonal change of tropospheric ozone residual and found a significant seasonal variation of tropospheric ozone residual in the middle and higher latitude.

Objectives

- to investigate the long-term trend of ozone in the lower-middle troposphere during the past twenty years over East Asia and the relation with anthropogenic emissions
- to classify the synoptic patterns causing the peak O_3 in the lower/middle troposphere over the past two decades

Objectives (cont.)

- to examine the relative roles of biomass burning, local photochemical production and intrusion of O_3-rich air from stratosphere in the enhancement of lower tropospheric O_3 using a 3-dimensional chemistry-transport model (e.g. WRF/Chem)

Objectives (cont.)

- to find the implication of tropospheric O_3 change in climate change and versus. Is there any relationship between ozone and temperature or relative humidity?

Methodology

- Ozone sounding data: once per week

  Hong Kong (lower latitude, 22^0N), sites in South Korea, Japan (along the coastal regions of Northwestern Pacific)

  - Variables: $O_{3,}$ temperature, relative humidity

  - Plots: vertical profiles of seasonal or annual mean, time-height cross section (t-z plots)

- Surface ozone data (like Hong Kong and Japan)

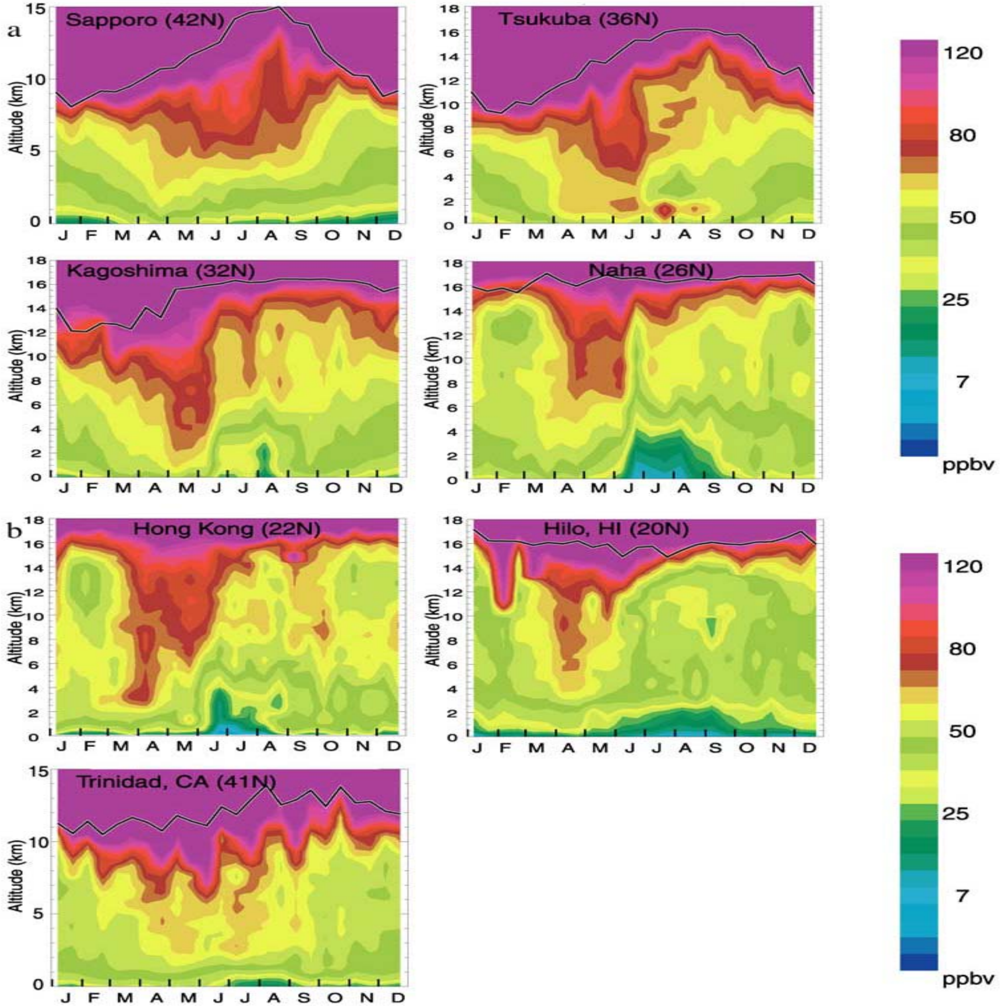
  - compare the change trend with lower/middle troposphere

Methodology (cont.)

- Reanalysis data (e.g., NCEP) : potential vorticity
- Weather charts: prevailing weather conditions (e.g. Anti-cycles system?, any relationship with Monsoon, ENSO?)
- 3-D Chemistry and Transport Model: Weather Research Forecasting (WRF) with Chemistry component (WRF/Chem) or Real Air Quality Modeling System (RAMS, a global model)

Ideas obtained from previous studies

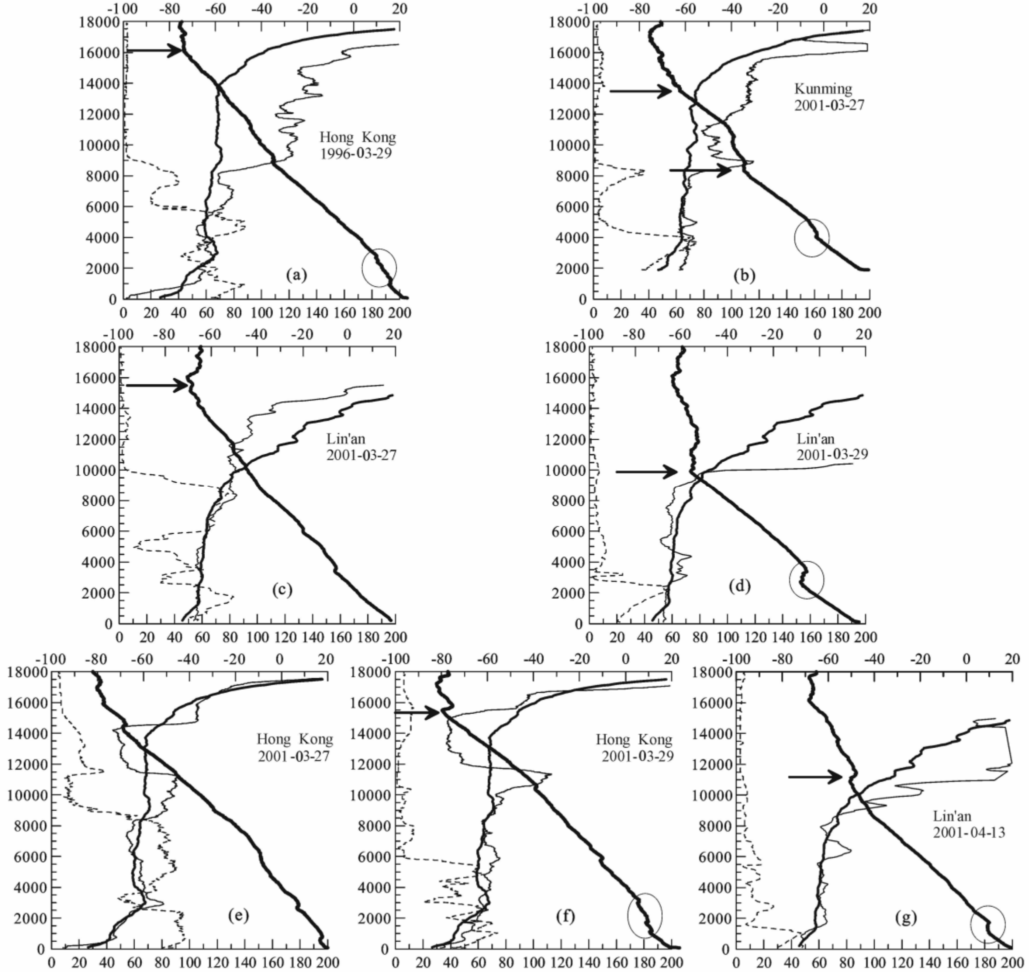
- Time-height cross section plots



S. J. Oltmans,1 B. J. Johnson, Tropospheric ozone over the North Pacific from ozonesonde observations, figure2

Ideas/examples obtained from previous studies (cont.)

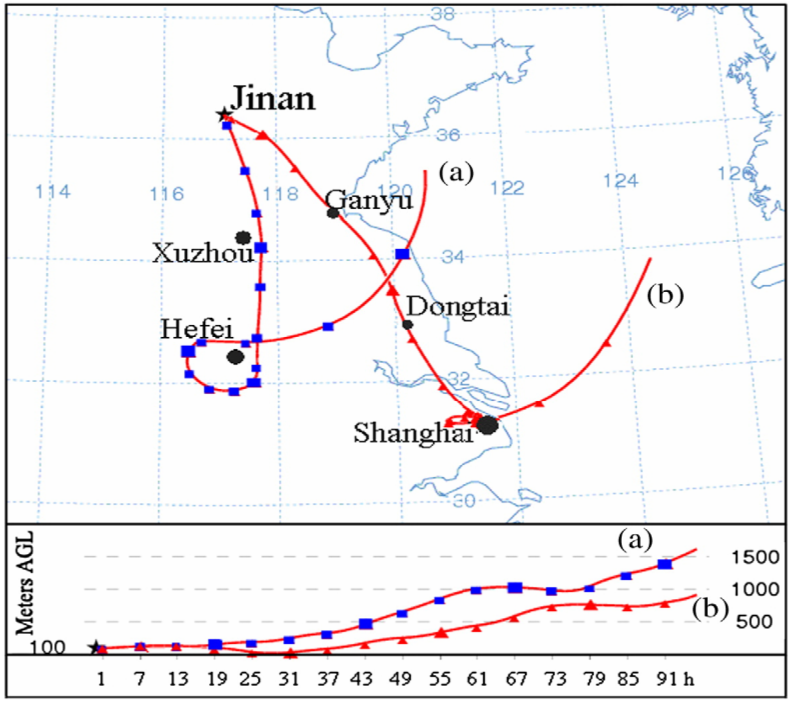
- **Vertical profiles of O_3, temperature, relative humidity, jet stream**

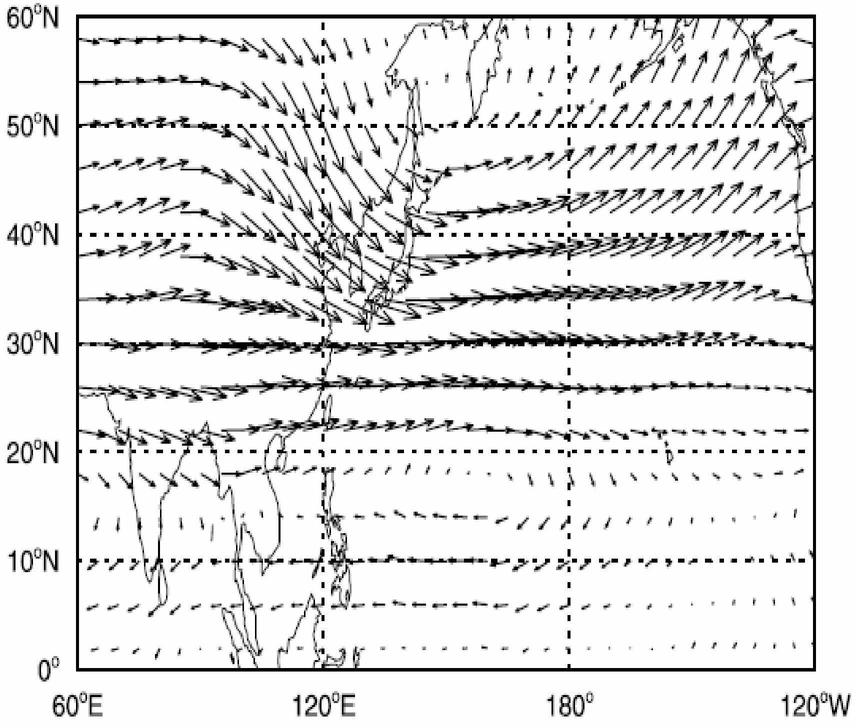


Zheng YongGuang ,Chen Jiong, Identifying method of ozone enhancement and multi-scale characteristics of ozone change in the mid-upper troposphere over South China ,figure1

Ideas obtained from previous studies (cont.)

- **Back trajectories and climatological wind fields will be used to identify the possible transport pathways.**

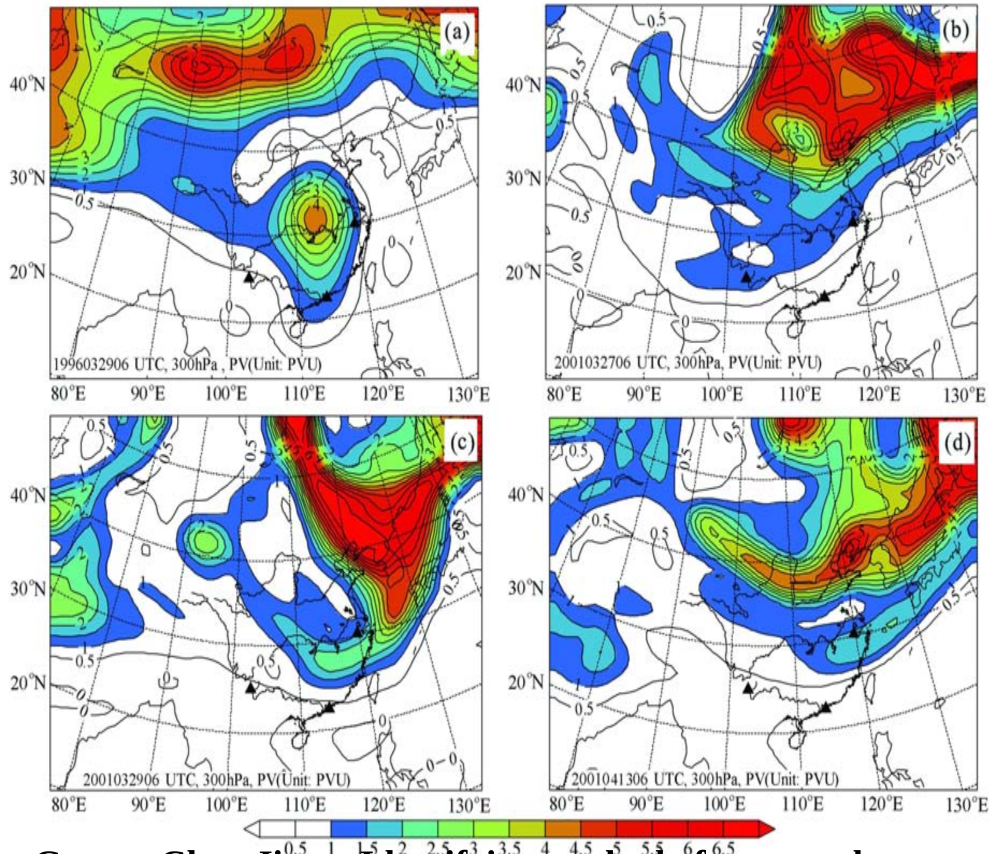




Wenpo Shan , Yongquan Yin. meteorological analysis of ozone episodes using HYSPLIT model and surface data, figure 4&6

Ideas obtained from previous studies (cont.)

- **PV to identify the stratospheric influence**



Zheng YongGuang ,Chen Jiong, Identifying method of ozone enhancement and multi-scale characteristics of ozone change in the mid-upper troposphere over South China ,figure4

Anticipated results

- Whether there is an increasing trend of O_3 in the lower/middle troposphere? Is there any relationship between increase in surface ozone (due to increase in anthropogenic emission) and lower/middle tropospheric ozone change?
- Why do different locations (latitude) have different ozone maximum seasons (e.g., Spring in Hong Kong, Summer in Japan)?
- What are the main features of synoptic patterns during the ozone maximum events? Can they be classified ? What are the dominant processes (regional transport or stratospheric intrusion) during different synoptic patterns of high ozone events?

Anticipated results (cont.)

- To revisit the unusually high O_3 events in the lower troposphere with a regional chemistry transport (e.g. WRF/Chem) or a global model (e.g., RAQMS) to identify the dominant processes.
- Is there any implication of tropospheric ozone change in climate change?

Comments and suggestions ?