Seasonal-yearly variation of ozone in the lower and middle troposphere over east Asia: An analysis of ozonesonde observations

Chenhong Zhou

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Outline

- Objectives
- Data and methodology
- Preliminary results
- Summary and conclusions
- On-going and future work

Objectives

- To quantify seasonal and long-term variations in lower/middle tropospheric ozone over East Asia
- To determine the relative importance of tropospheric photochemical production and stratospheric intrusion in the seasonal variation
- To classify the synoptic patterns associated with the peak O_3 in the lower/middle troposphere

O_3 Sounding Data

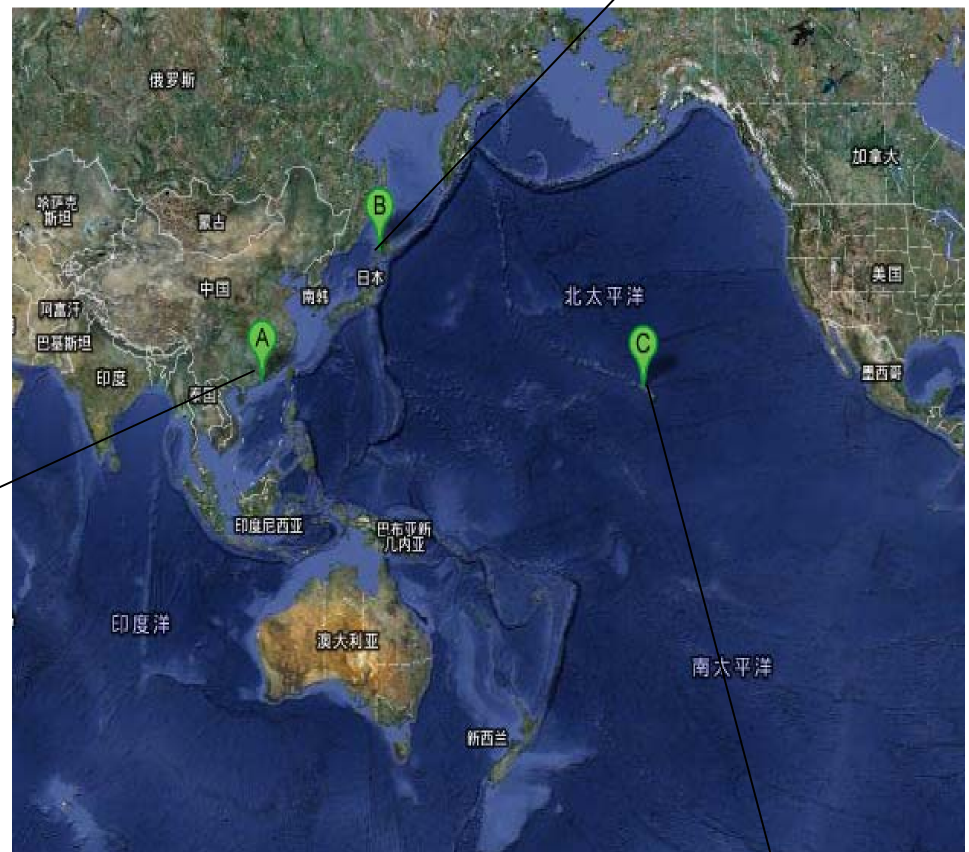
- Three observational sites:

Station	Latitude longitude	Observation	Number of observations
Hong kong	22.3° N, 114.7° E	2000-2010 (2002;2003)	432
Sapporo	43.1° N, 114.7° E	2000-2010	477
Hilo	19.7° N, 155.1° E	2000-2010	497

- Variables: Pressure , O_3 partial pressure, temperature
  Wind speed, Wind direction, Geo-potential
  height, Relative humidity

Observational Sites

Sapporo (JPN 43.1° N， 141.3° E)



HK（22.31° N，114.71° E）

Hilo(19.72° N，155.07° E)

Methodology

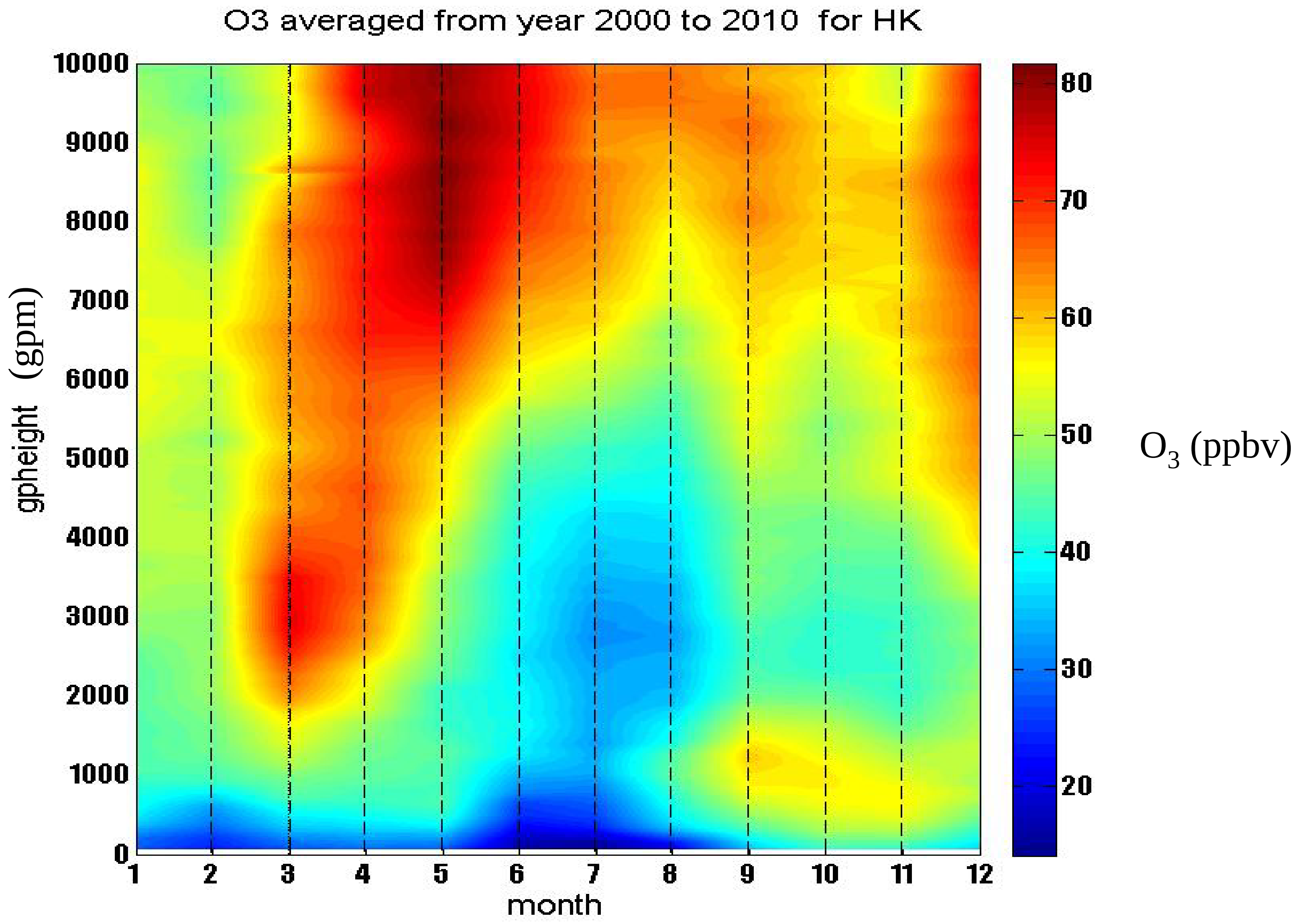
1) According to Dalton's law, ozone mixing ration (ppb) is calculated by

$$C_X = P_X / P$$

where P_X is partial pressure of gas x (O_3 here), P is the total pressure. Both P_X and P are obtained from ozone sounding measurements.

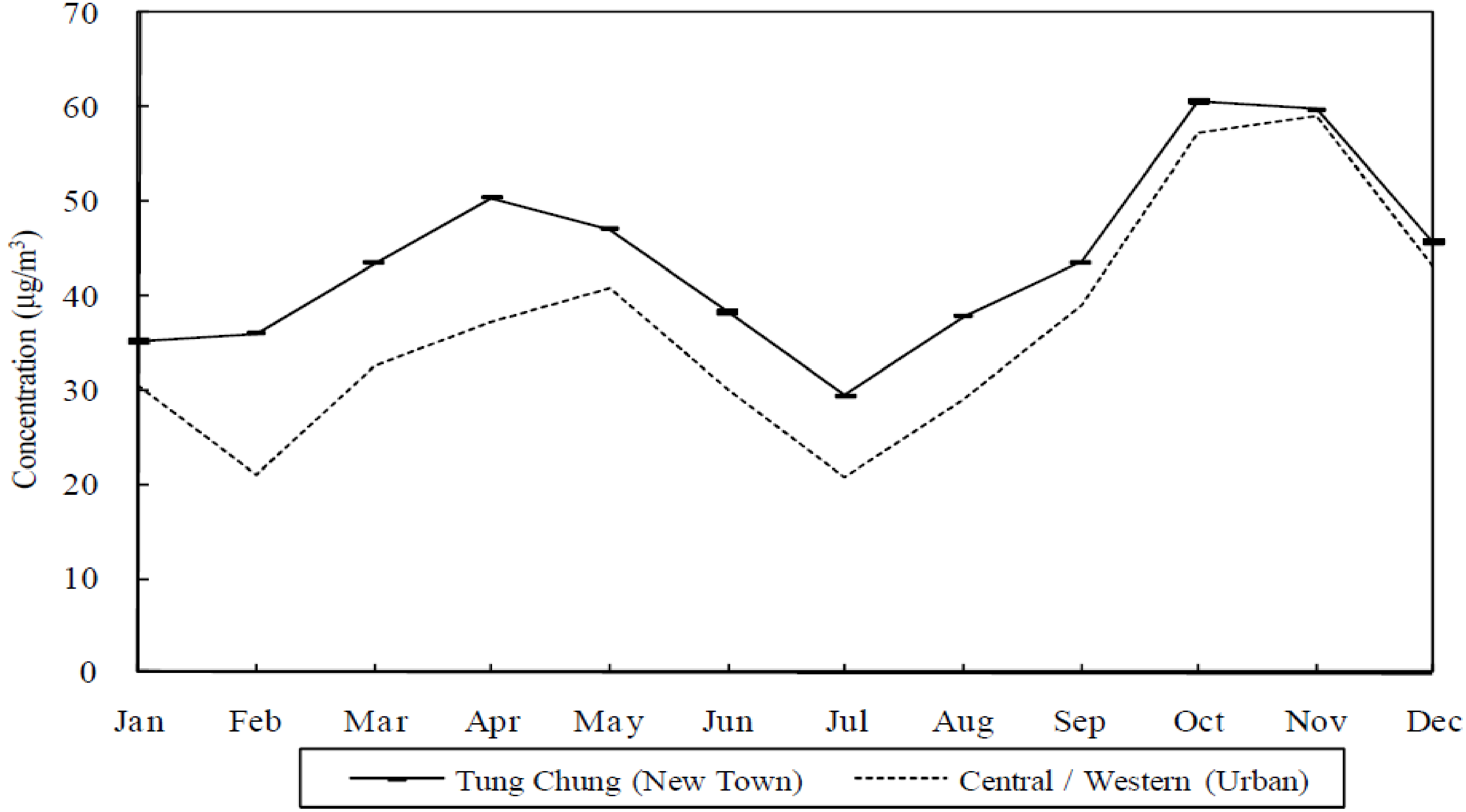
2) O_3, RH are linearly interpolated from the measured heights to the fixed level at vertical resolution of 20 m.

Month-Height Cross Section of O_3 at HK



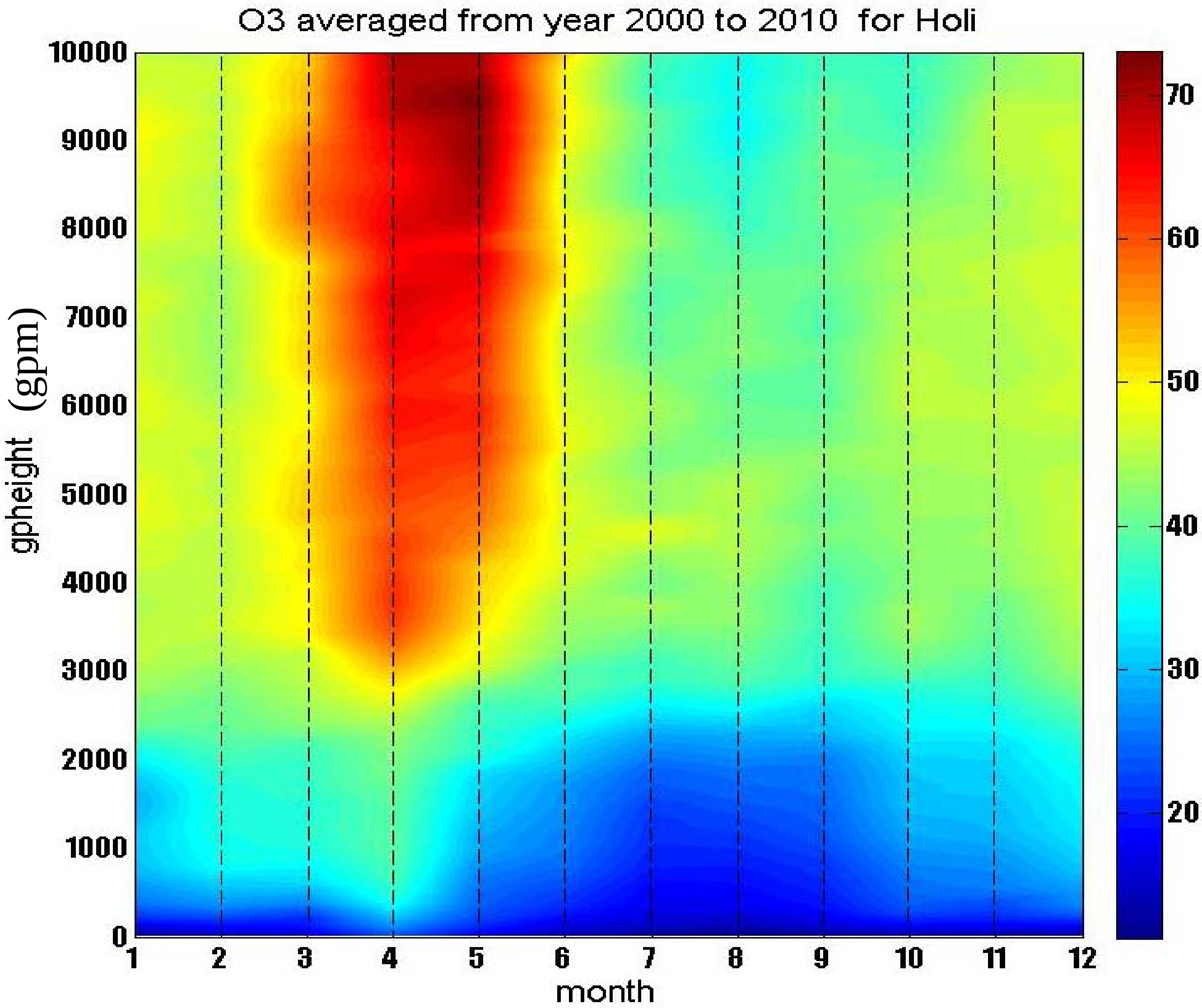
Linking to monthly variation of surface O_3 at HK

Monthly variation pattern of O_3 in 2010



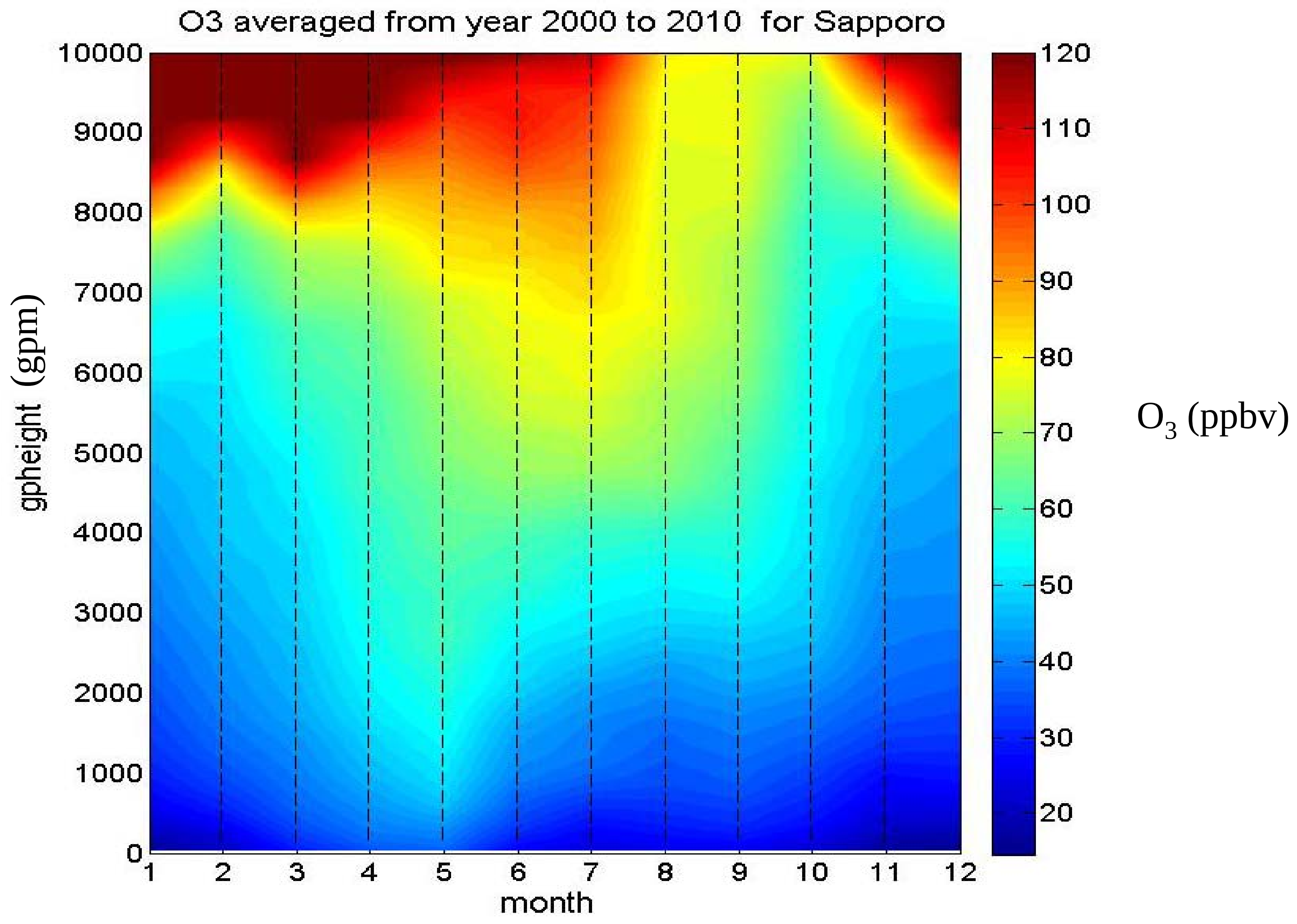
(Source : Hong Kong EPD's report)

Month-Height Cross Section of O_3 at Hilo

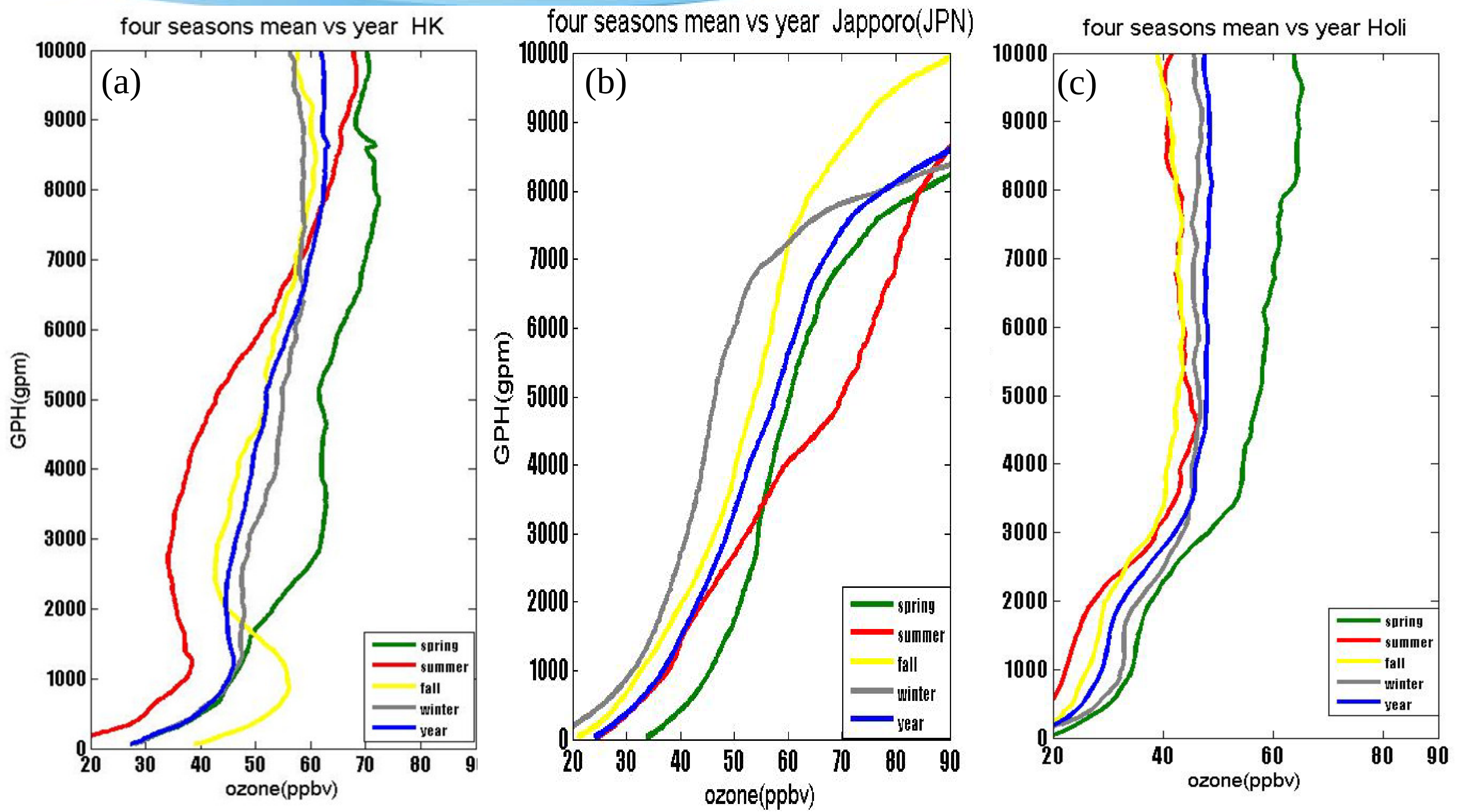


O_3 (ppbv)

Month-Height Cross Section of O_3 at Sapporo

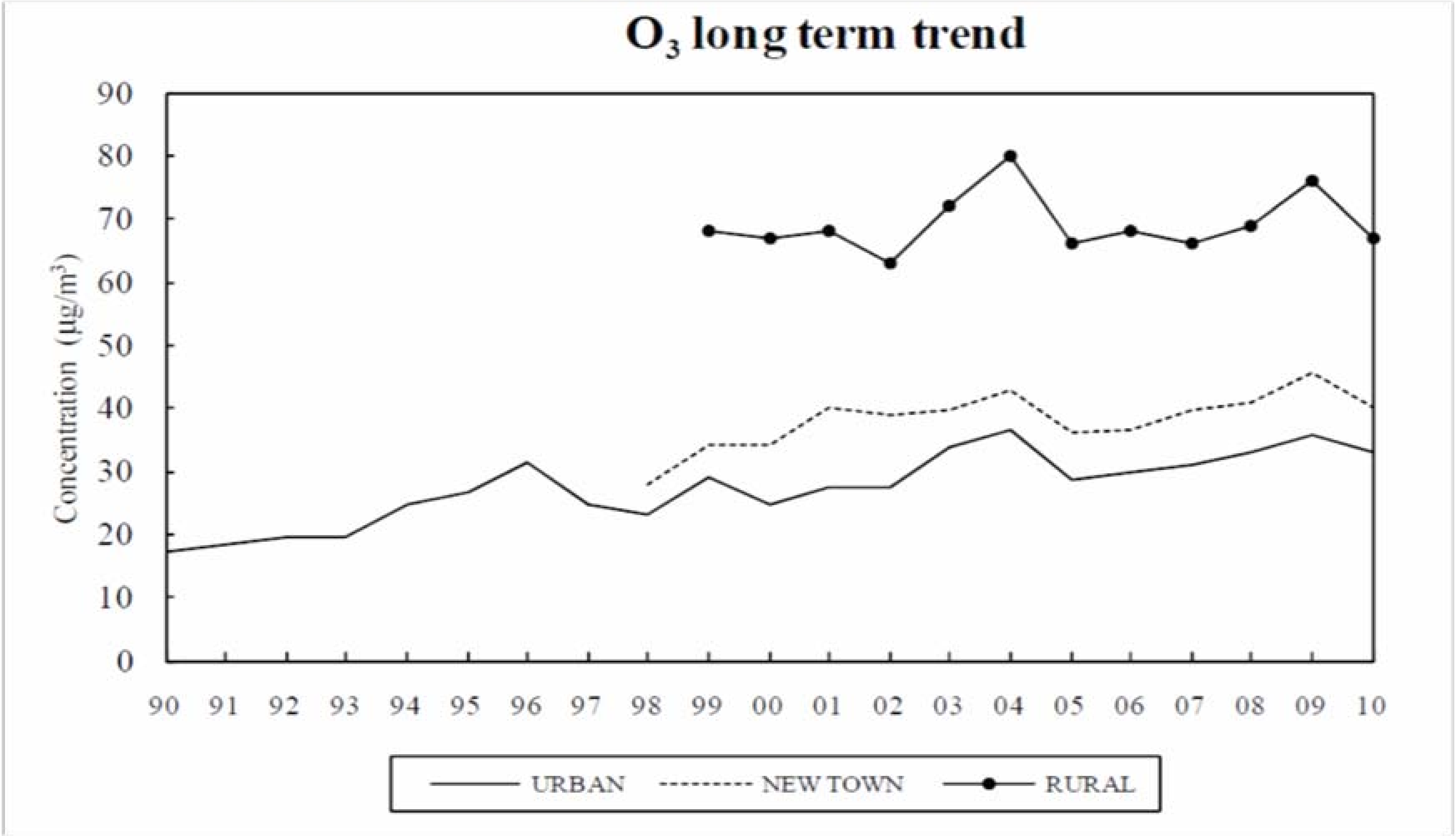


Seasonal and yearly variations of O_3



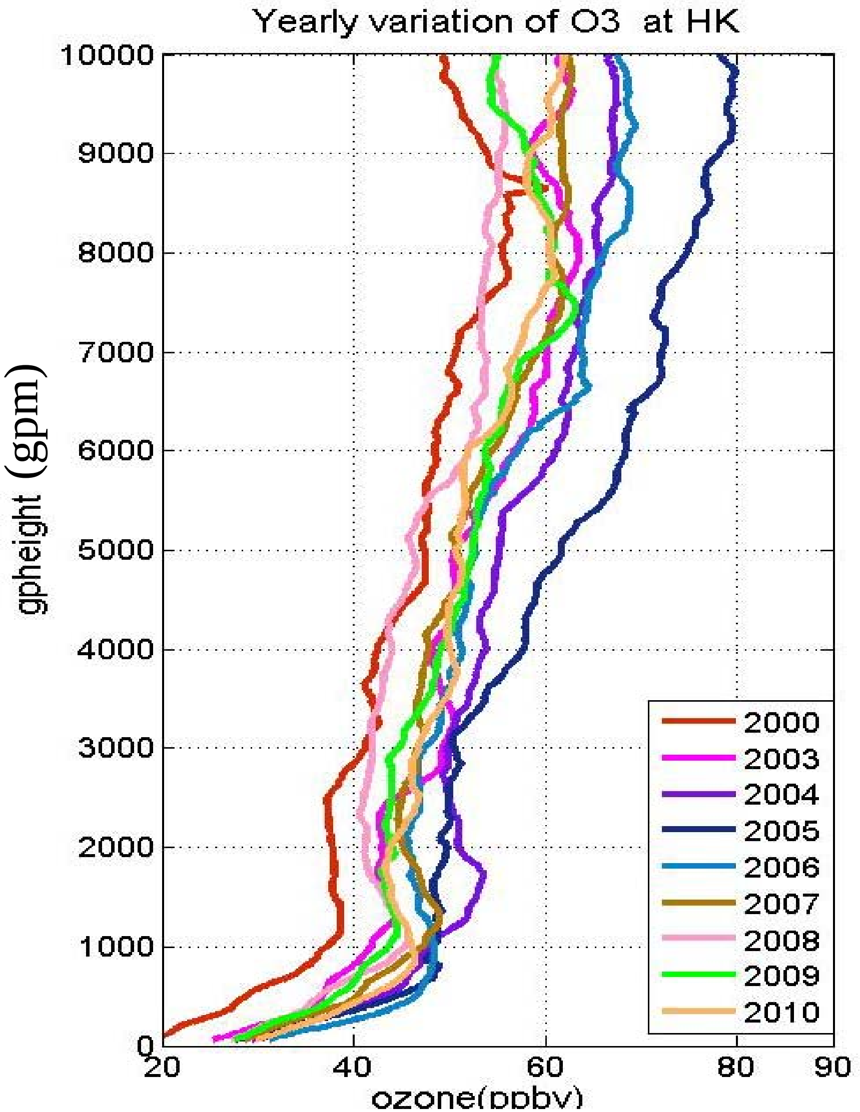
Averaged over the year 2000 to 2010 at a) Hong Kong, b) Sapporo ,and c) Hilo

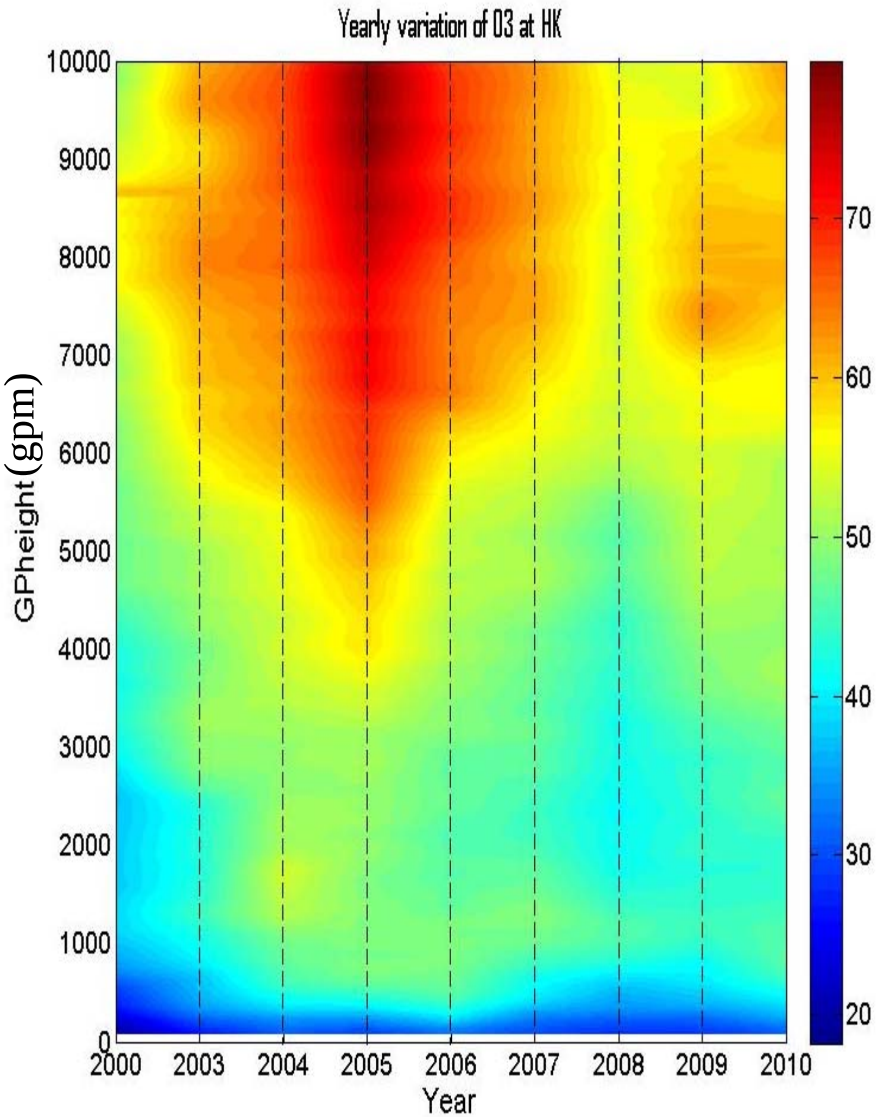
Long term trend: Surface O_3 in HK



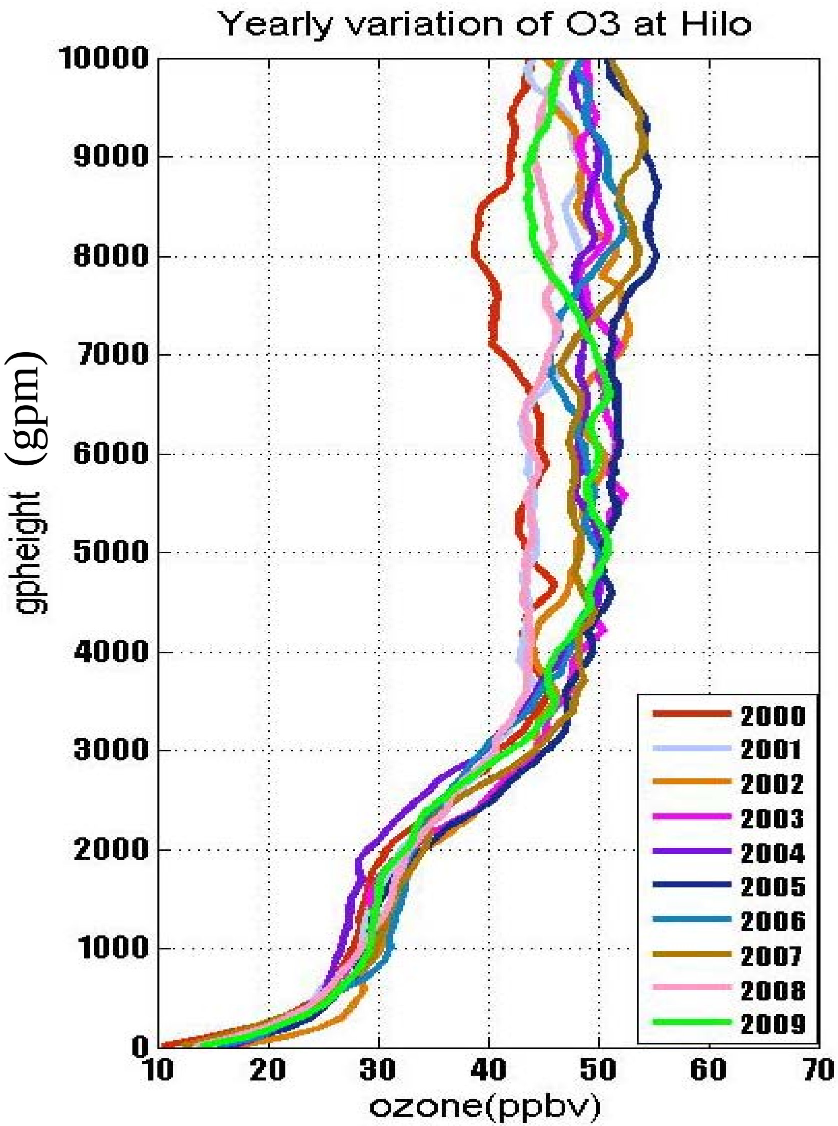
Source: Hong Kong EPD

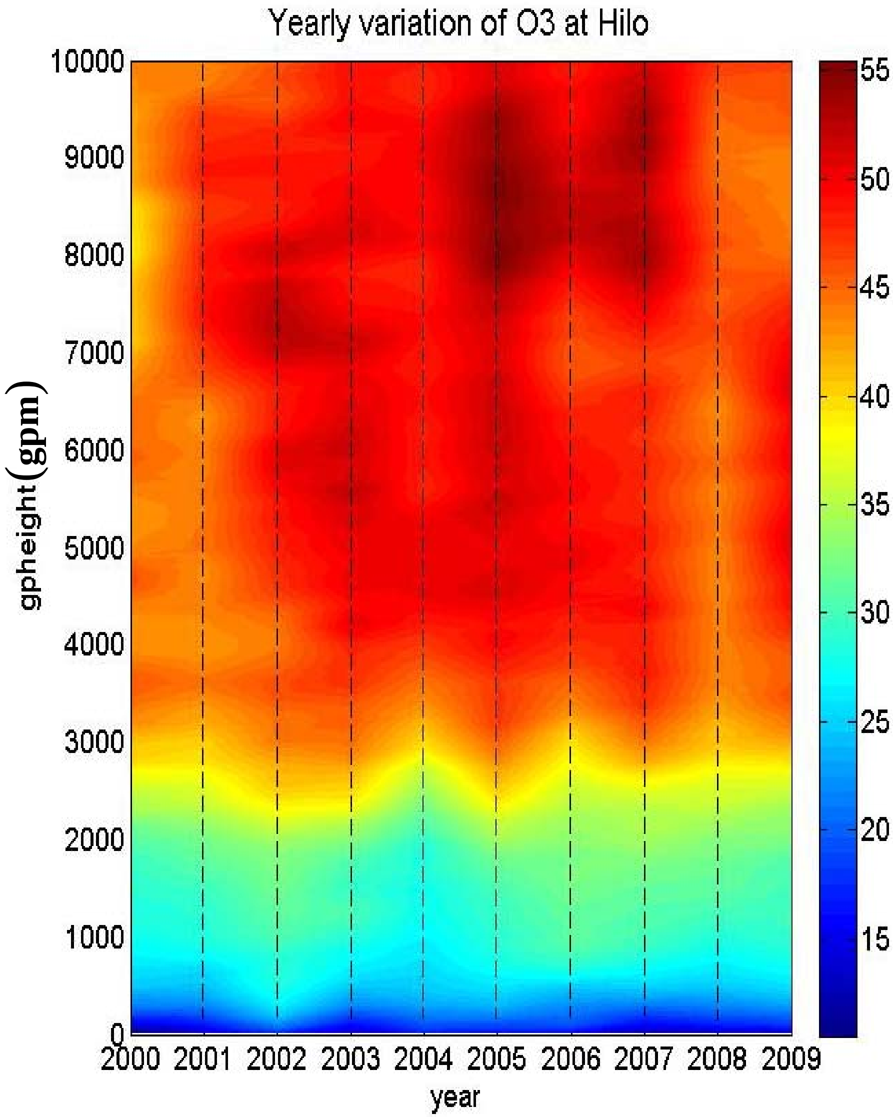
Yearly variation of O_3 at HK



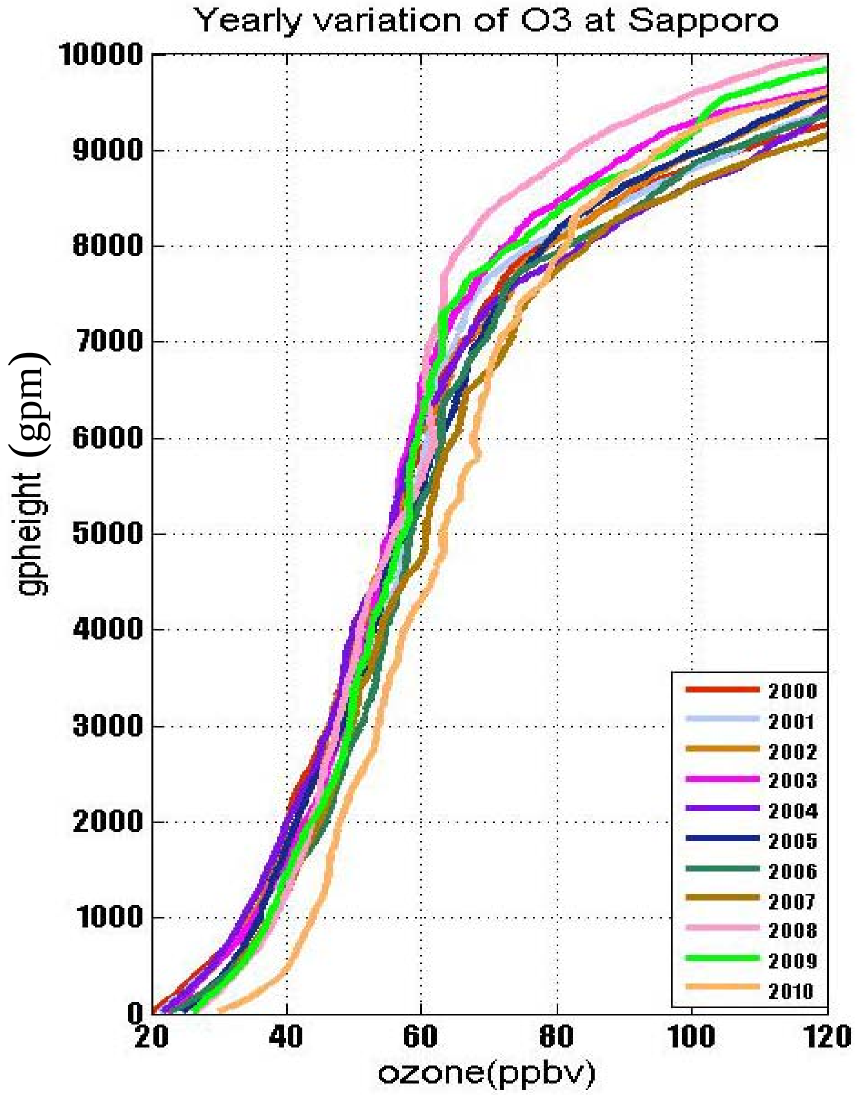


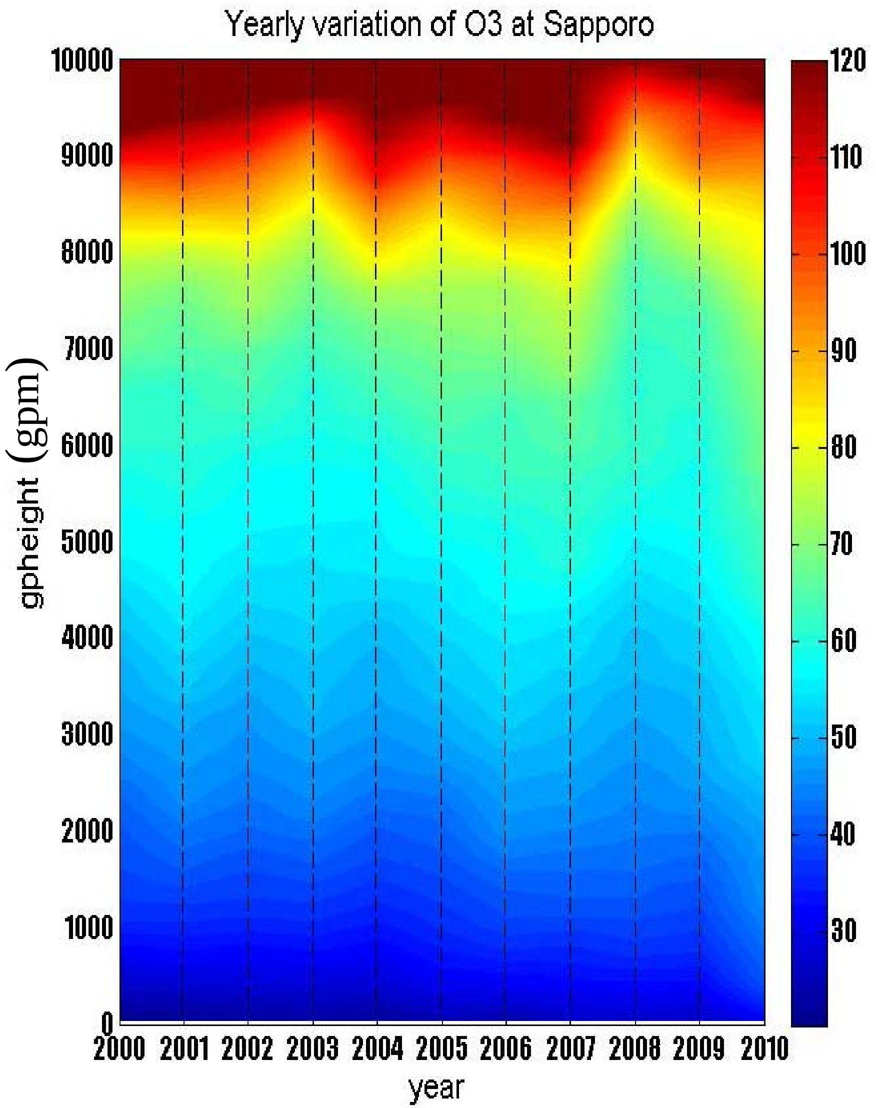
Yearly variation of O_3 at Hilo



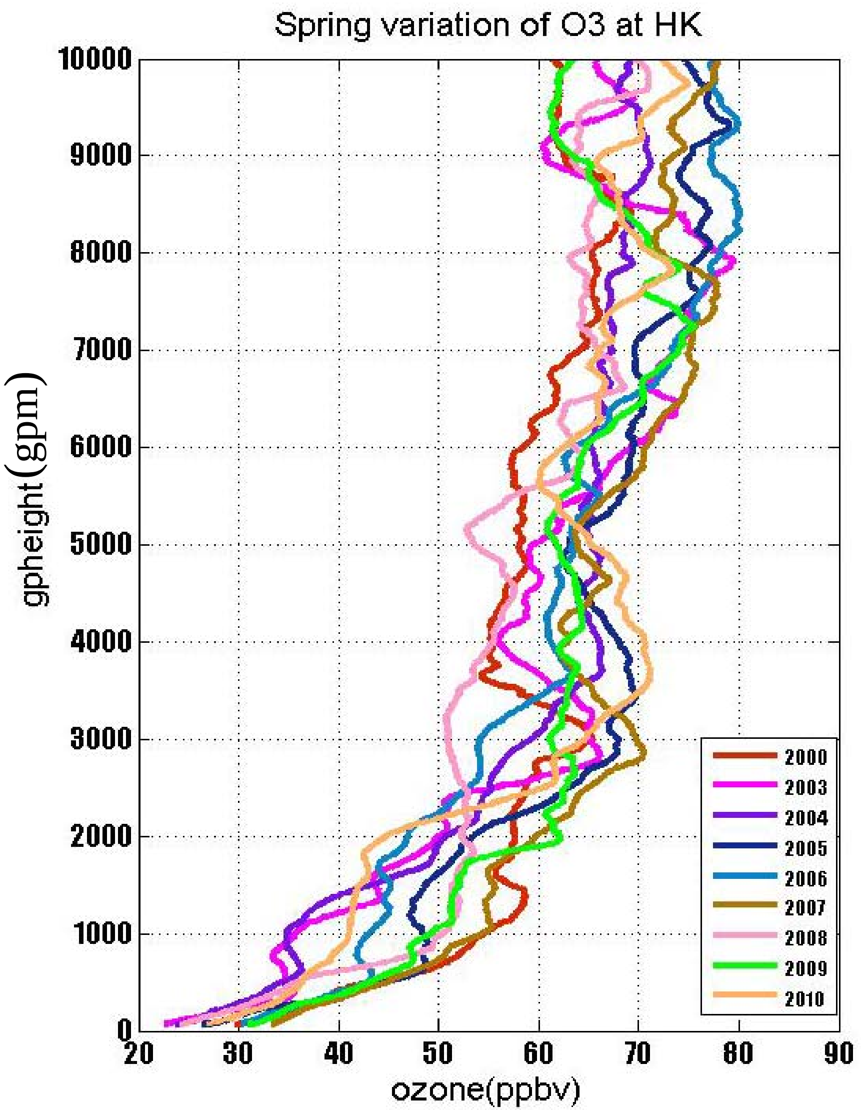


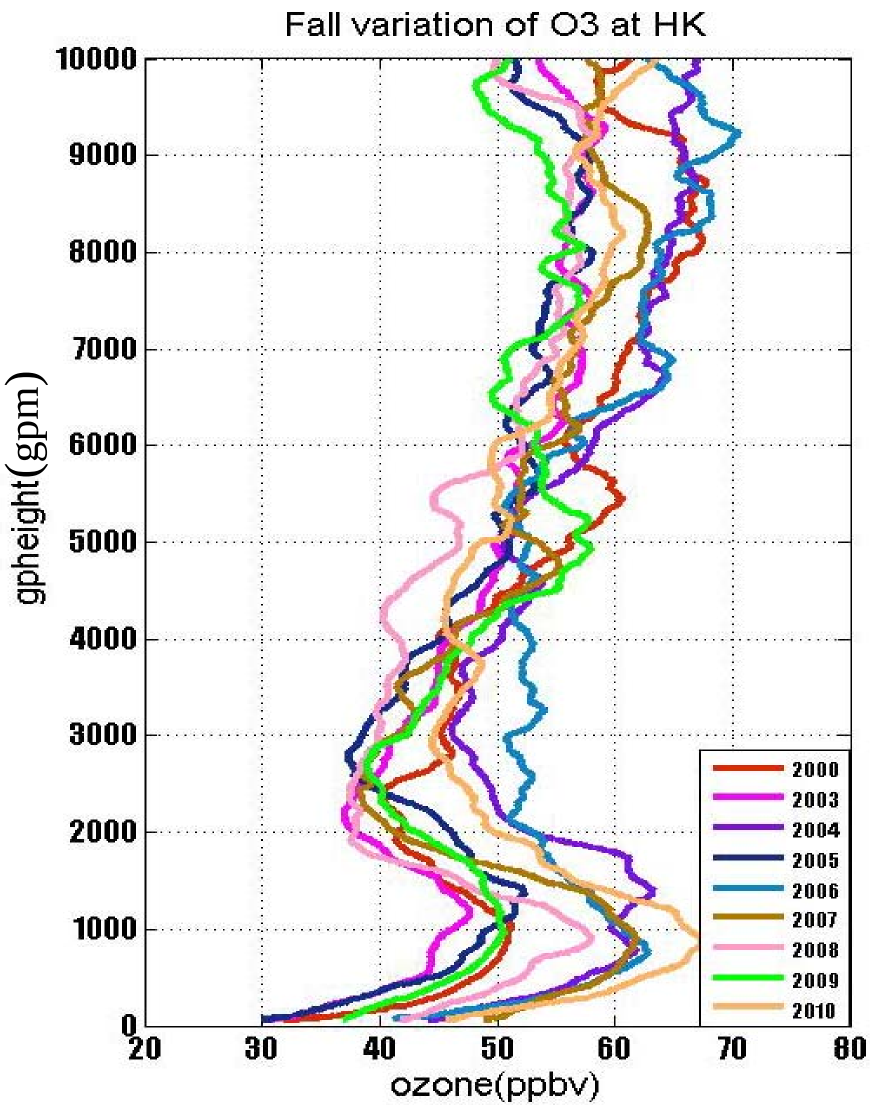
Yearly variation of O_3 at Sapporo



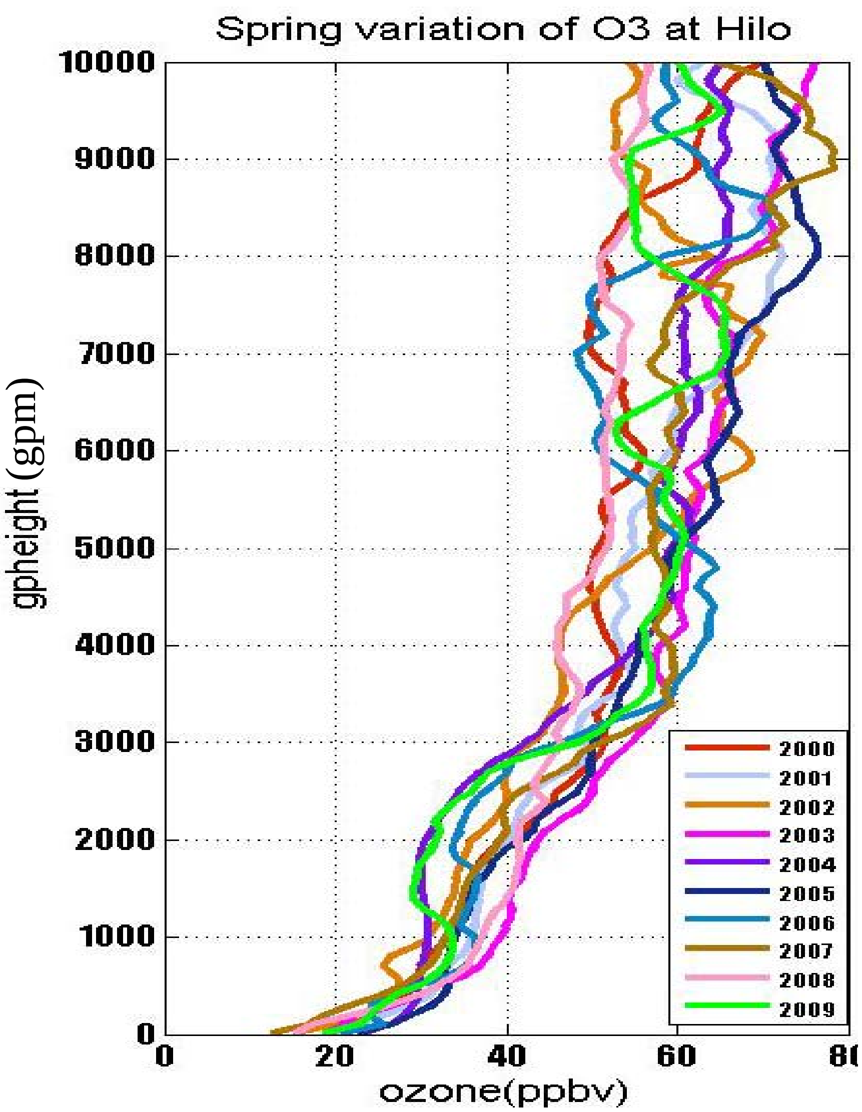


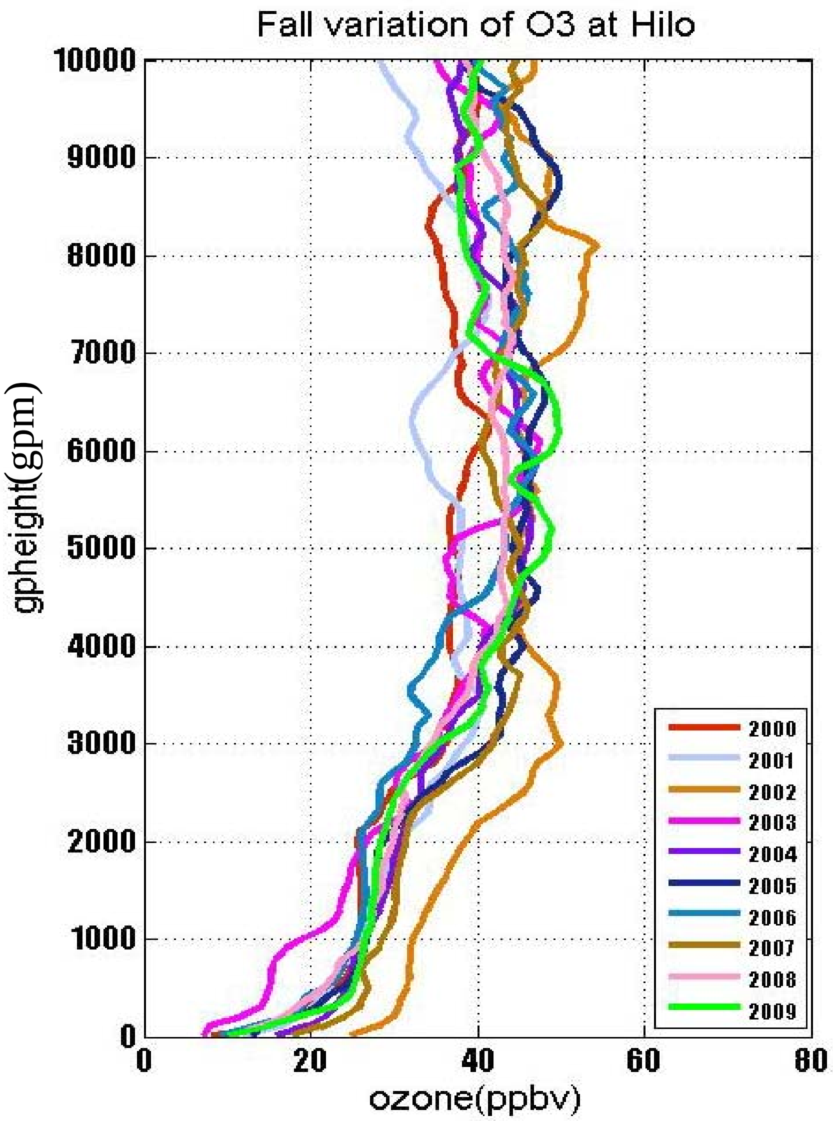
Spring/fall variation of O_3 at HK



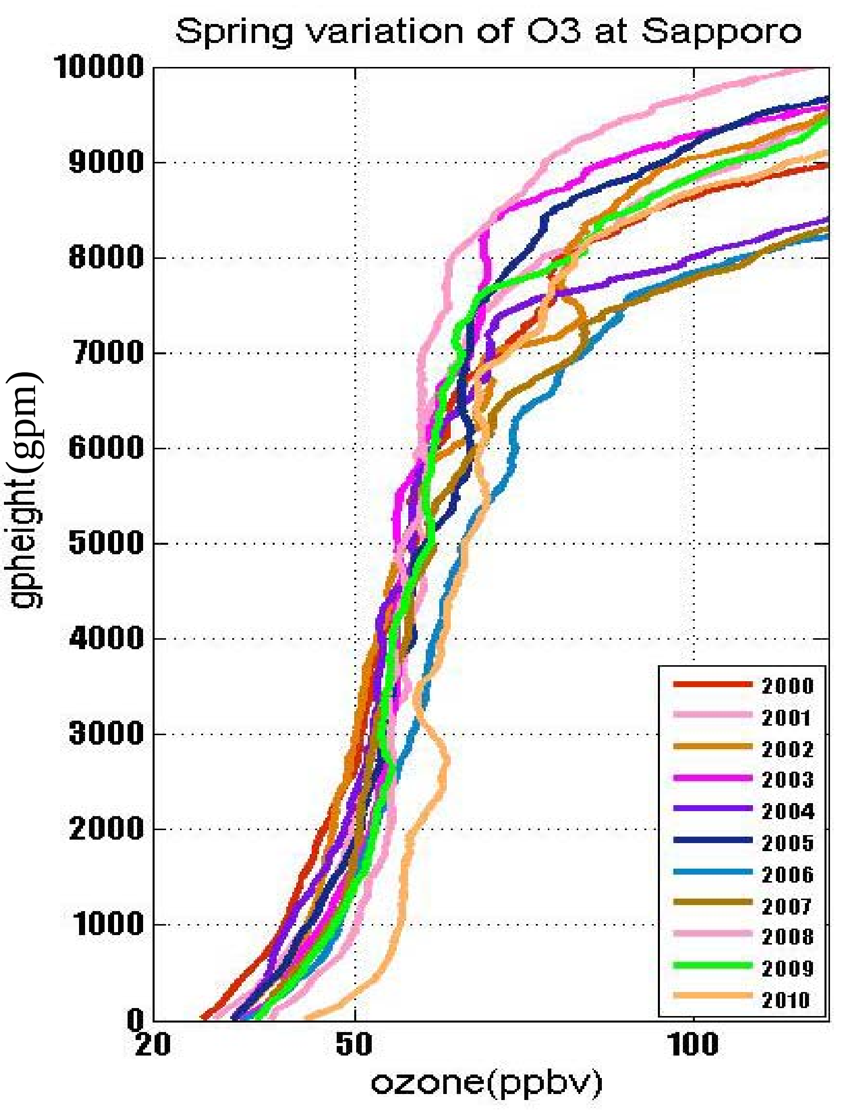


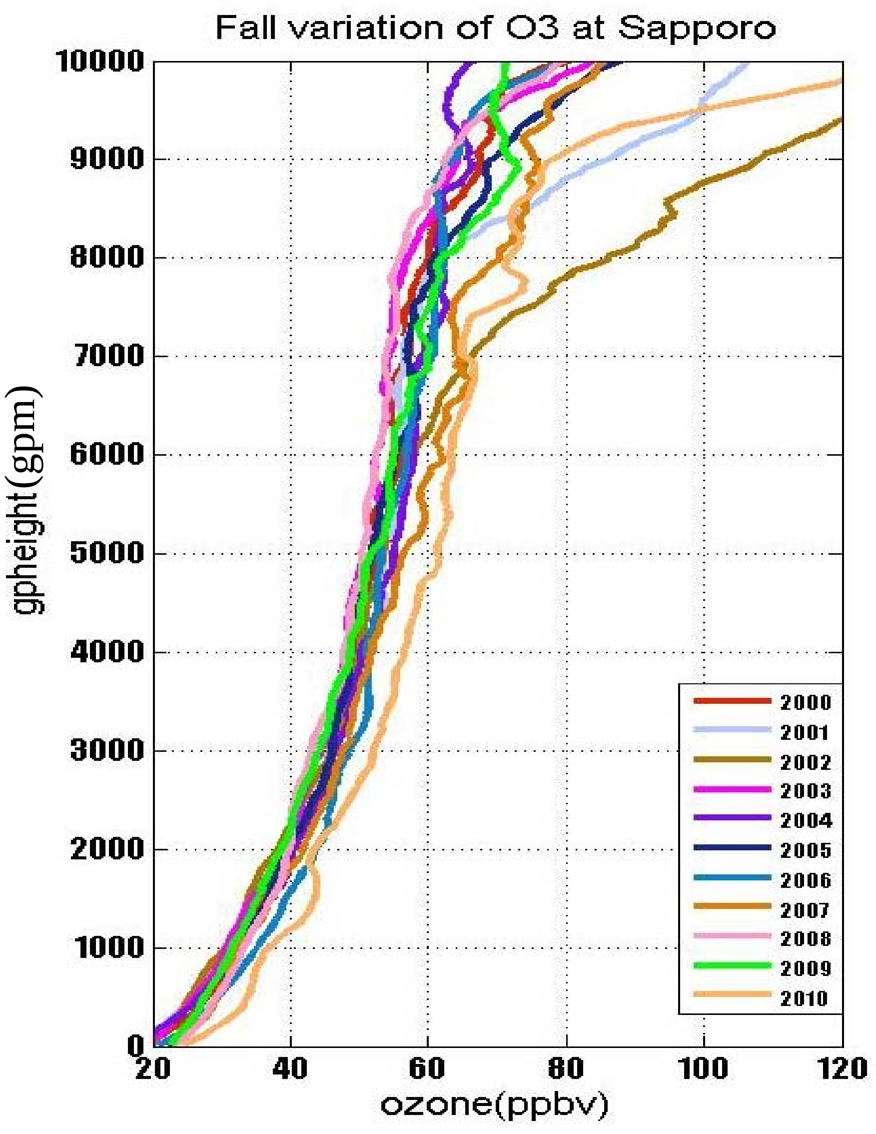
Spring/fall variation of O_3 at Hilo

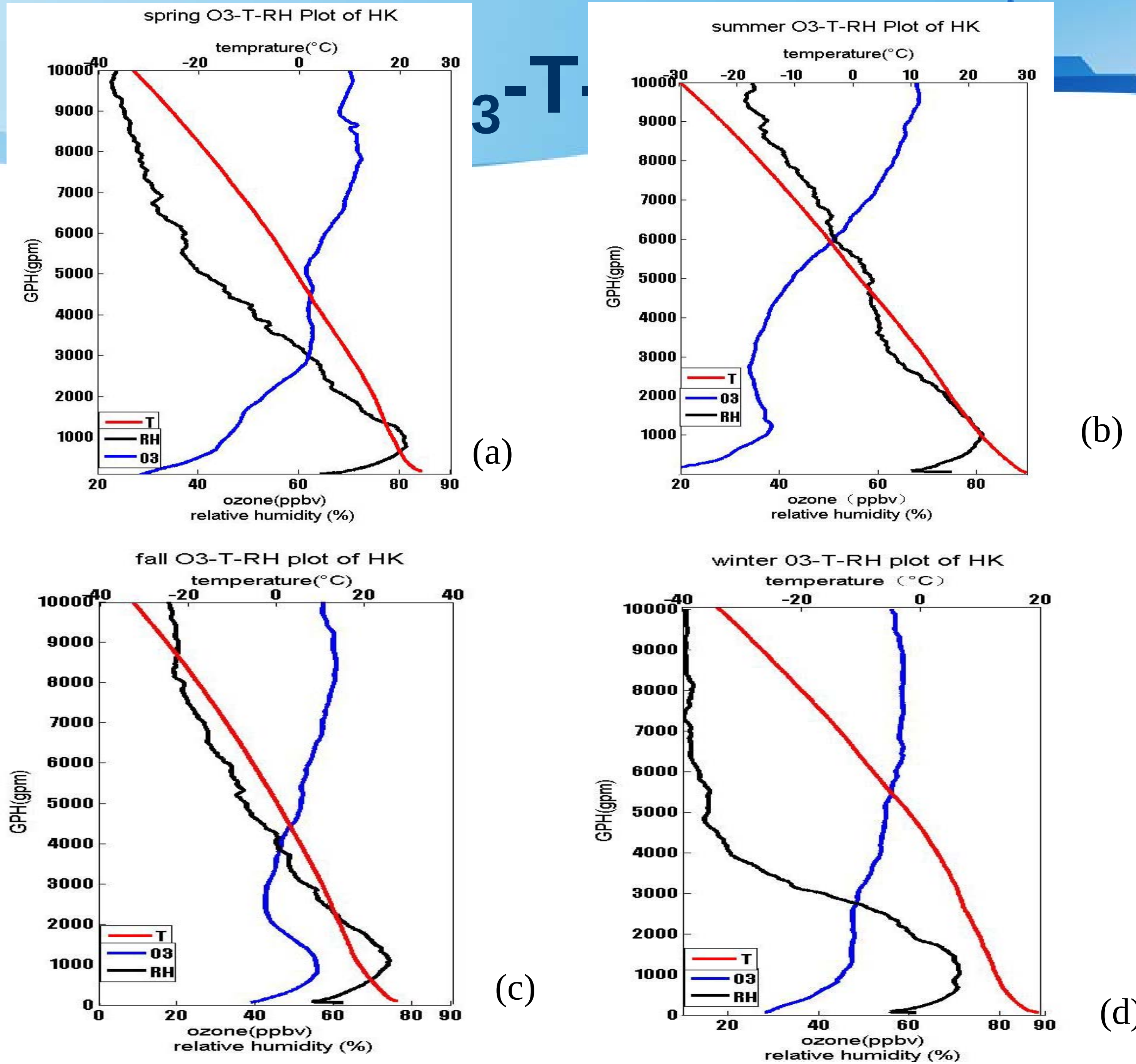




Spring/fall variation of O_3 at Sapporo






spring O3-T-RH Plot of HK
temprature(°C)
GPH(gpm)
ozone(ppbv)
relative humidity (%)
T
RH
03
(a)
summer O3-T-RH Plot of HK
temperature(°C)
GPH(gpm)
ozone（ppbv）
relative humidity (%)
T
03
RH
(b)
fall O3-T-RH plot of HK
temperature(°C)
GPH(gpm)
ozone(ppbv)
relative humidity (%)
T
03
RH
(c)
winter 03-T-RH plot of HK
temperature（°C）
GPH(gpm)
ozone(ppbv)
relative humidity (%)
T
03
RH
(d)

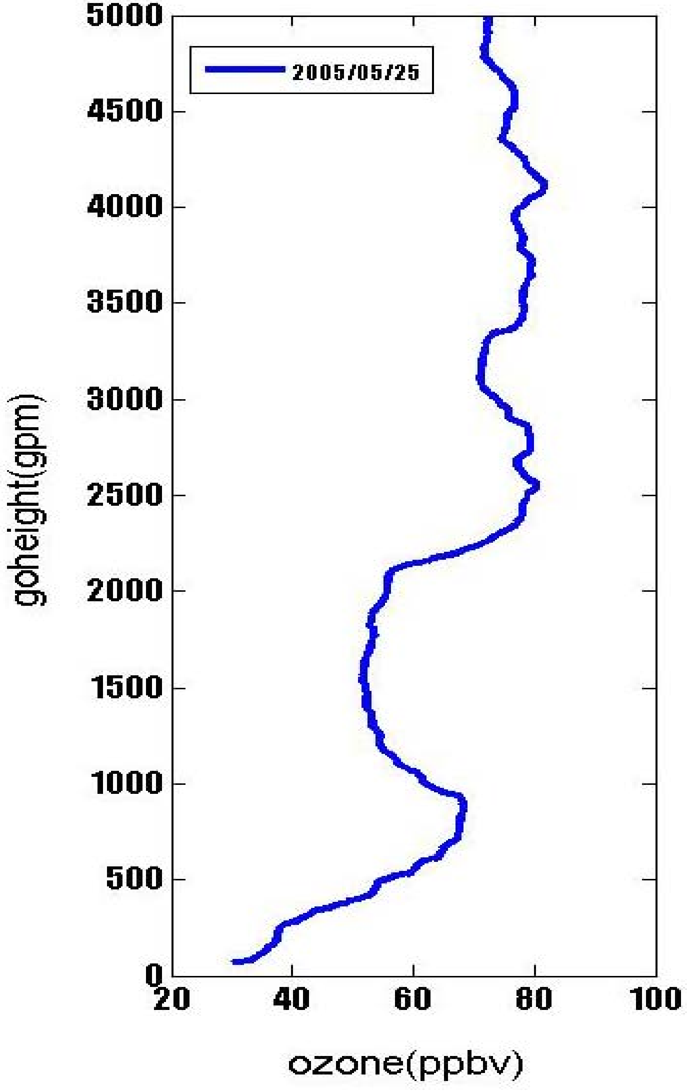
Synoptic patterns

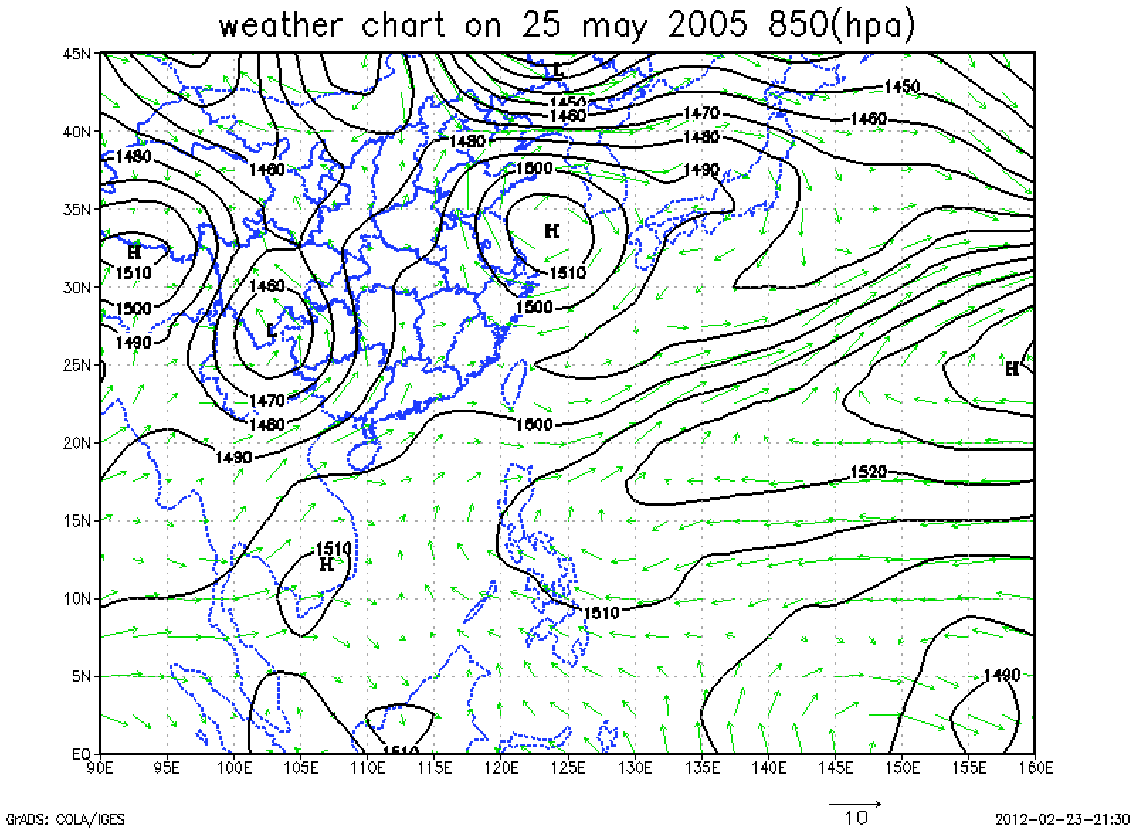
Table 3. Synoptic Meteorology and Weather Conditions of Ozone Episodes

Types	Dominant Surface Pressure Patterns	Major Flow Patterns and Surface Winds in Hong Kong	Weather and Atmospheric Conditions	Period of Frequent Occurrence
Northerly (N)	continental anticyclone over northwestern China	straight northerly anticyclonic flow from Mainland China as north or northeast winds	dry, clear sky and occasionally cold and strong wind	Dec. to March
Weak northerly (wN)	moderate or weak continental anticyclone over northwestern China	weak and straight northerly anticyclonic flow from Mainland China as weak north or northwest wind	dry and clear sky	Oct. to early Dec.
North-easterly (NE)	continental anticyclone over northeastern China, East China Sea, and southern Japan	northeasterly anticyclonic flow from East China Sea and Taiwan Straits as northeast and east winds	dry, clear sky and long sunshine hours	late Sept. to mid. Mar.
Easterly or southeasterly (E)	anticyclone centered east of 130° E and north of 20° N	easterly or northeasterly anticyclonic flow as east or southeast winds	fairly long sunshine hours	mid. Apr. to mid May
Trough (T)	low-pressure trough with axis extending approximately east-west over south China	northerly anticyclonic flow to the north of trough and easterly cyclonic flow to the south; wind is variable	low wind and stagnant atmosphere	late May to early Jun.; mid. Aug. to mid. Sept.
Southerly or southwesterly (S)	Quasi-stationary low-pressure area over Asian continent	cyclonic flow from the South China Sea as south or southwest wind	high temperature and strong solar radiation	June. to Aug.
Pacific ridge (P)	ridge of Pacific high-pressure extending to Taiwan and southeastern China	straight flow from the Pacific Ocean as east or southeast winds	high temperature and strong solar radiation	June. to Aug.
High-pressure cell (H)	weak high pressure cell over south China	weak anticyclonic flow with weak surface winds	clear sky, long sunshine hours and low wind	early Sept.; late April to late May
Cyclone (C)	Hong Kong within circulation of a traveling cyclone	cyclonic flow as north or northwest winds	low-level inversion, hot, clear sky, and long sunshine hour	May to early Dec.

Source: Y. Chan and L. Y. Chan, 2000

synoptic patterns





synoptic patterns

- Light winds on 25 May correlated to the presence of a weak high pressure system over the southern part of China. Well-defined boundary layer, light winds, high solar radiation ,such conditions promote photochemical O_3.

- Largescale weak northerly winds were deflected at Victoria Harbor to a northwesterly or westerly direction. This help transport of the pollutants emitted from both sides of the harbor and possibly from areas farther north of Kowloon to the HK island.

Summary and conclusions

- Consistent with other studies, in spring, especially March and April, high ozone center (yearly average of 70~80 ppb) occurs around 2~4 km AGL in HK. But our analysis shows the stratospheric intrusion plays the most important role in the spring ozone enhancement in the lower troposphere, which is different from the finding in some other studies.
- An interesting finding is that high ozone concentrations are also observed in the atmospheric boundary layer (< 2km) in autumn at HK. This is mainly related to local photochemical production and regional transport from the PRD region (anthropogenic contribution). This phenomenon is not observed at Hilo and Sapporo sites.

Summary and conclusions (cont.)

- The seasonal variation in HK is more evident than other two sites. In HK, the O_3 max season in the lower to middle troposphere is different from that at the surface. The max O_3 occurs in spring for in the upper level whereas the O_3 max season is fall at the surface. This is not observed in Hilo and Sapporo. In Hilo, the max O_3 extends through from the surface to the upper level and the min O_3 season is summer. However, in Sapporo, the min O_3 season is winter.

Summary and conclusions (cont.)

- Surface O_3 shows a steady increasing trend over the past 20 years. However, this trend is not clear in the lower to middle troposphere. There are two reasons for this. First, it probably is due to insufficient ozone sounding data (weekly sampling may be not enough to resolve this). Second, the surface contribution is not competitive with the contribution from the upper levels (e.g., stratospheric intrusion).

On-going and future work

- Further analysis of ozone sounding data: Necessary
- Classification of weather charts associated with ozone peak cases in the lower atmospheric layer (2~4km) in spring and in Hong Kong: sort out the cases and download surface, 850 hpa, 700 hpa weather charts and then to see whether they can be classified.
- Combing observational analysis with numerical model, WRF/Chem to better understand the processes or mechanism causing the spring peak ozone cases in HK.


Thank you !!!