Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

A discussion on the paper " CO_2 and its correlation with CO at a rural site near Beijing: implications for combustion efficiency in China"

Huang Wenjing

2016/09/16

Outline

- Background
- Material & method
- Results and discussion
- Conclusions

Background

- CO_2 is an important greenhouse gas in atmosphere which is influenced by a number of factors.
- China has surpassed the United States as the world's largest carbon emitter in 2006, but its overall CO_2 budget has large uncertainties.

Background

- In situ measurements of atmospheric CO_2 have been sparse in China , whereas bottom-up emission inventories of CO_2 require an extensive network of CO_2 observations.
- CO is a product of inefficient combustion that has often been used as a tracer of CO_2 from combustion and the CO_2/CO correlation slope provides a signature of the source region's combustion efficiency.

Material & method

Location: 40°29′ N, 116°46.45′ E

Prevailing winds: northwestly & southwestly

Period: 51 months (2004.12-2009.2)

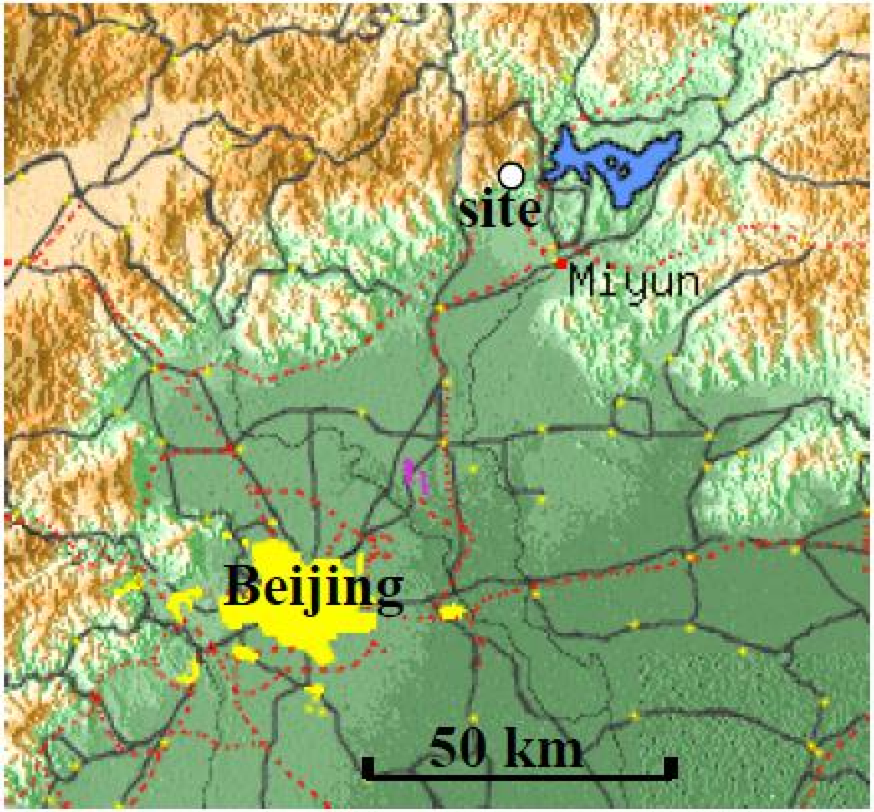


Fig. 1. A regional map shows the location of the site (white circle) relative to Beijing urban area and other population centers (yellow), major roads (red), airport (magenta), and terrain. The color shading indicates elevation from low (green – near sea level) to high (darkest brown corresponding to 1400 m). Miyun city is indicated by the red dot. Reproduced from Wang et al. (2008)

Material & method

Table 1. Data for continuous observations

	Data	Frequency
Investigative gases	CO, CO_2	hourly
Basic meteorological data	*T*, RH, wind speed, wind direction	——
other pollutants	O_3, NO, NO_y,SO_2	——

Material & method

- CO mixing ratios are measured by infrared absorption (Thermo Environmental Instruments 48CTL) (wang et al. 2008).

- The CO_2 mixing ratio is measured by the differential nondispersive infrared (NDIR) method (LI-COR Biosciences Li-7000).

Results and discussion

General statistics of CO_2

- Diel variations

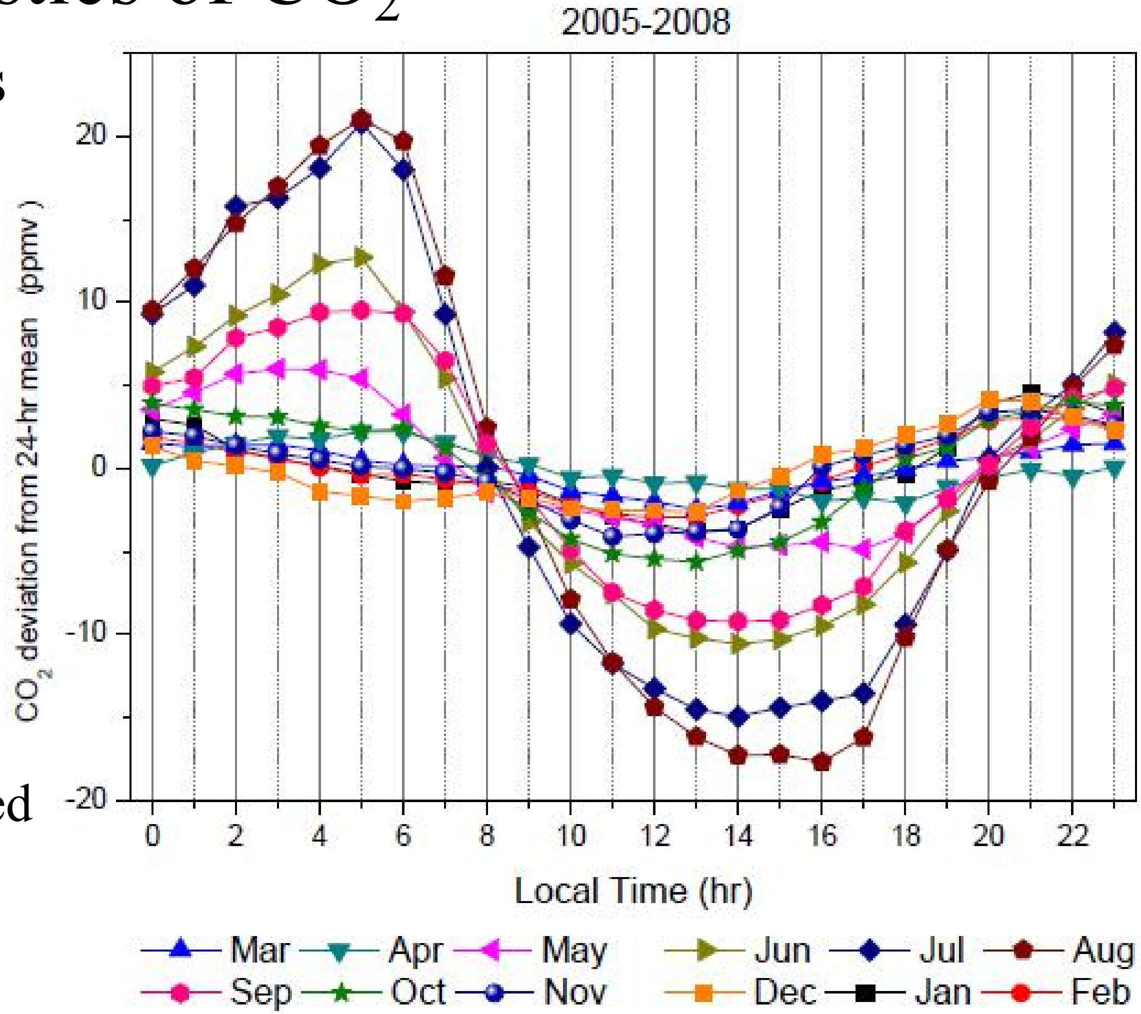
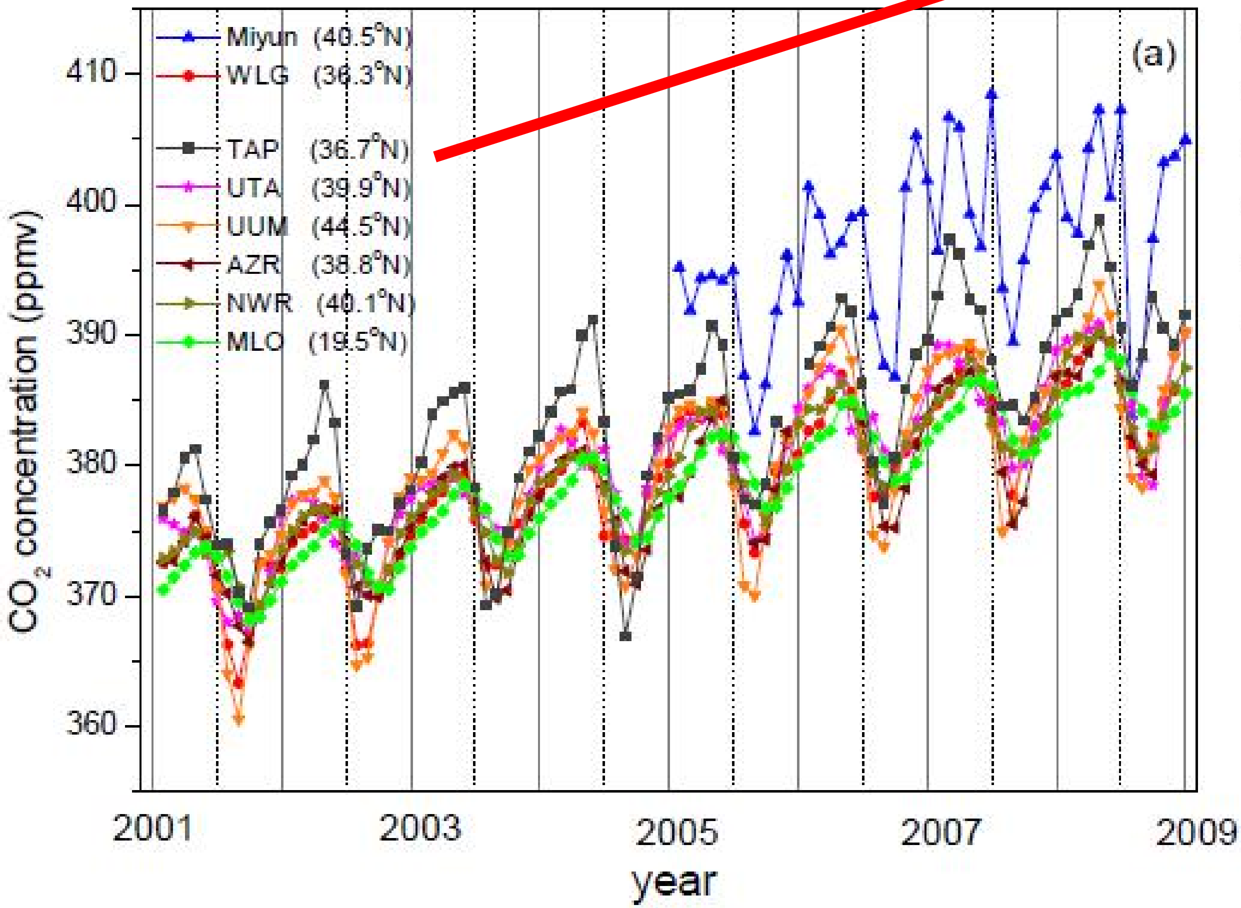


Fig. 2. Mean standardized diurnal variation of CO_2 by month at Miyun (2005–2008).

Results and discussion

- Seasonal variations



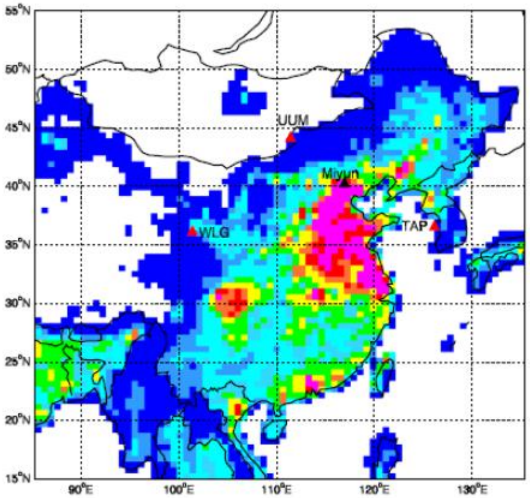
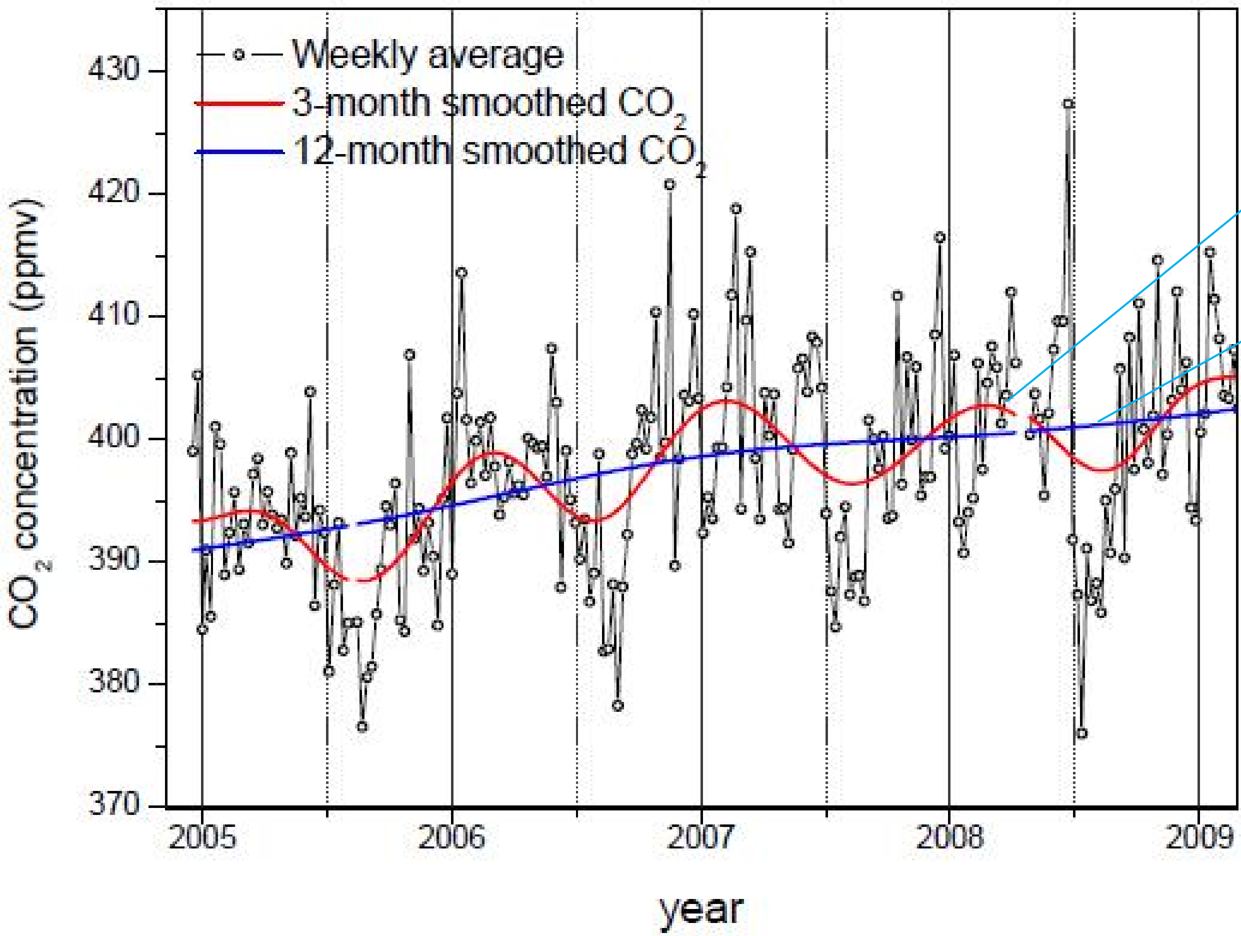


Fig. 3. Monthly mean CO_2 at Miyun site and several NOAA/ESRL sites.

Results and discussion

- Seasonal variations



7.4ppmv

2.7ppmv per year

Fig. 4. Weekly mean CO_2 at Miyun from December 2004 to Februar 2009 (black line).

Results and discussion

- Interannual variations

Table 2. Descriptive statistics of CO_2 observation from 2005 to 2008.

	2005	2006	2007	2008
mean (ppmv)	392.17	397.02	399.62	400.35
median (ppmv)	389.31	394.89	396.17	397.59
min (ppmv)	350.75	349.30	343.66	352.57
max (ppmv)	478.21	481.59	488.77	467.92
Data completeness	78.0%	81.7%	92.6%	84.4%

Results and discussion

CO_2-CO Correlation

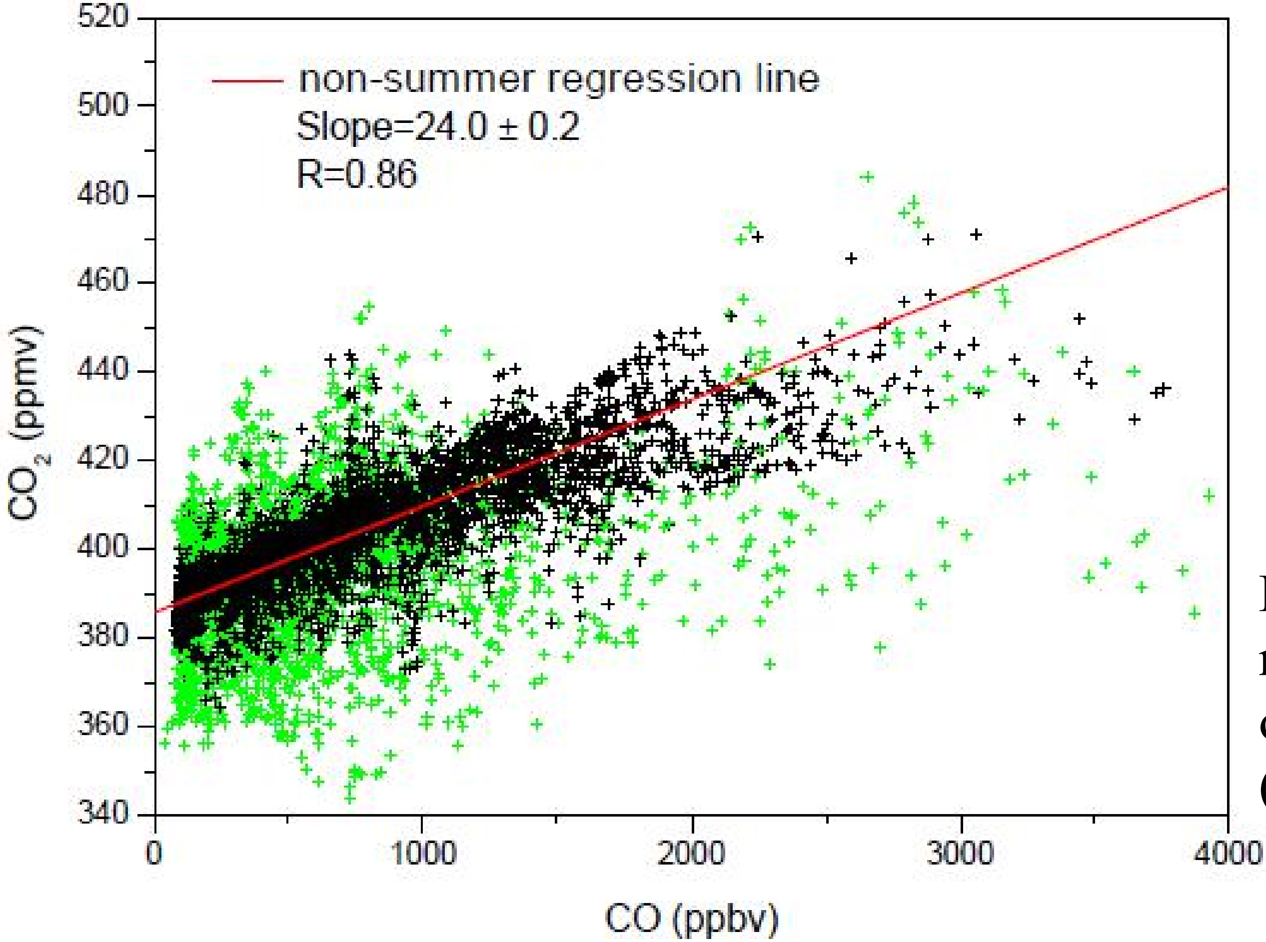


Fig. 5. CO_2-CO relationship observed at Miyun (2007.3 – 2008.2).

Results and discussion

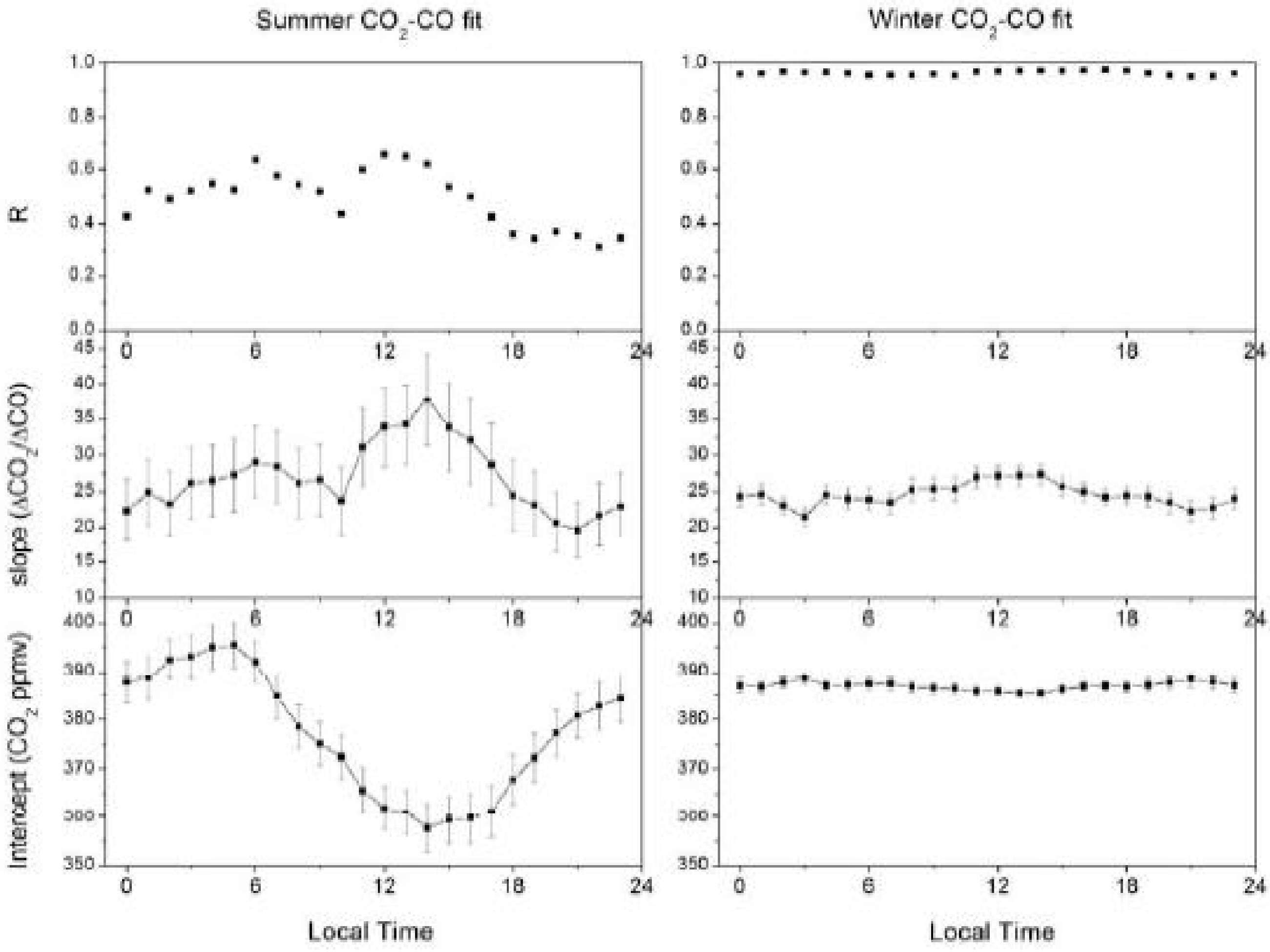


Fig. 6. The correlation coefficients (R), correlation slope (dCO_2/dCO), and intercepts of CO_2-CO regression at Miyun as a function of local time for summer (left) and winter (right), 2007.

Results and discussion

Background CO_2

$$CO_{2,b} = CO_{2,i} + CO\big|_{5\%} \times dCO_2/dCO$$

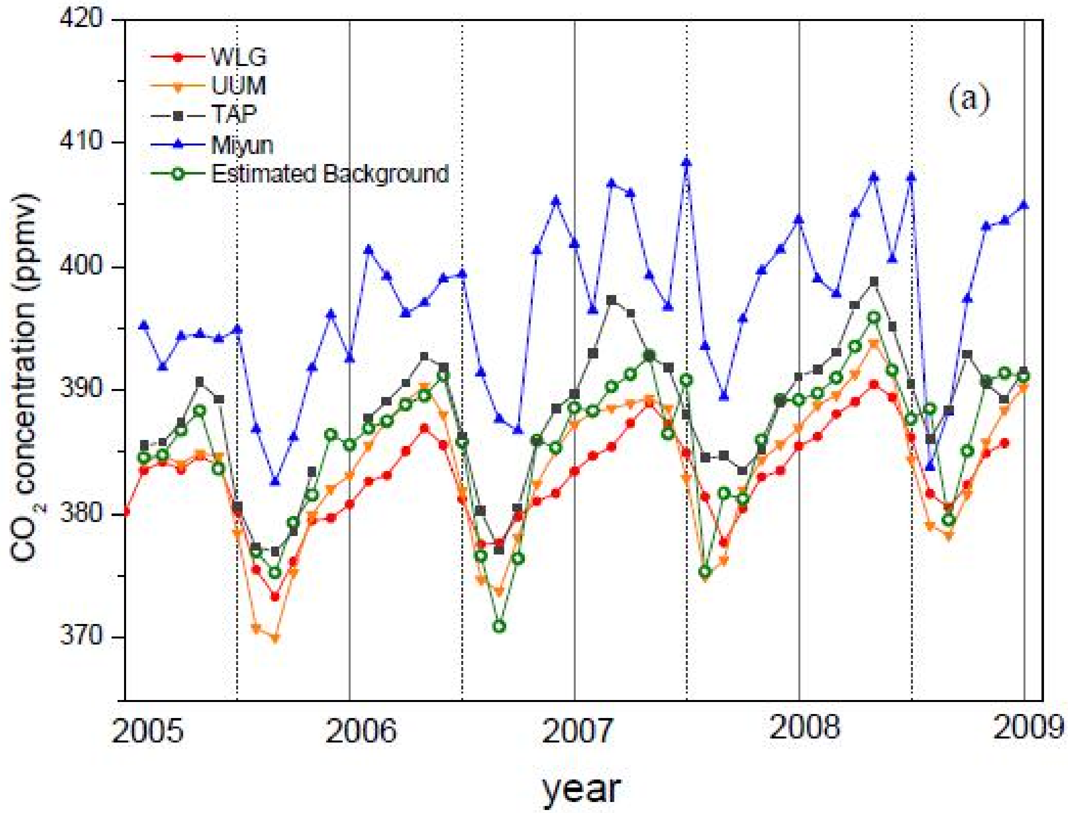


Fig. 7a. Background CO_2 (a) derived at Miyun (green) compared to three ESRL sites (WLG, UUM, and TAP).

Results and discussion

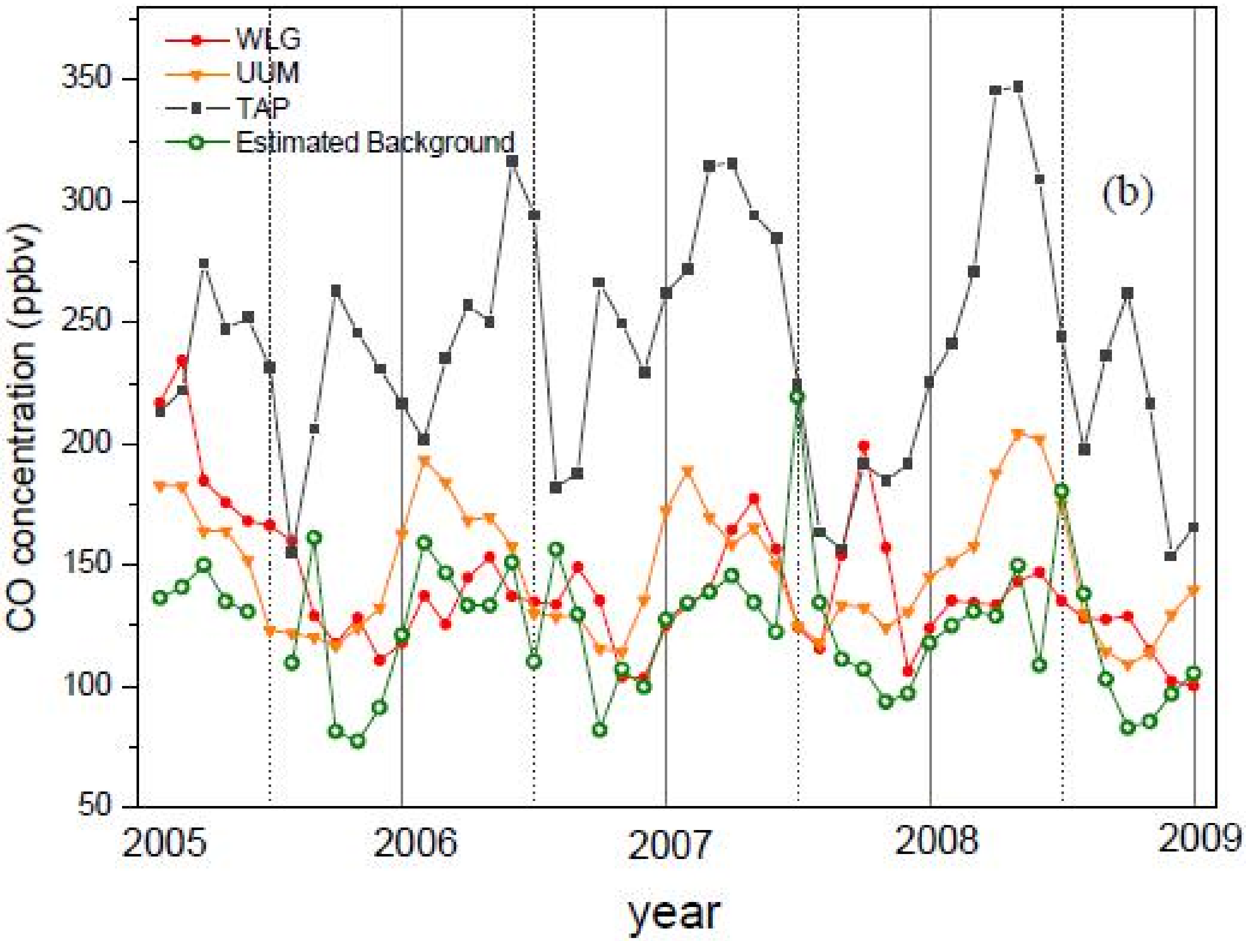
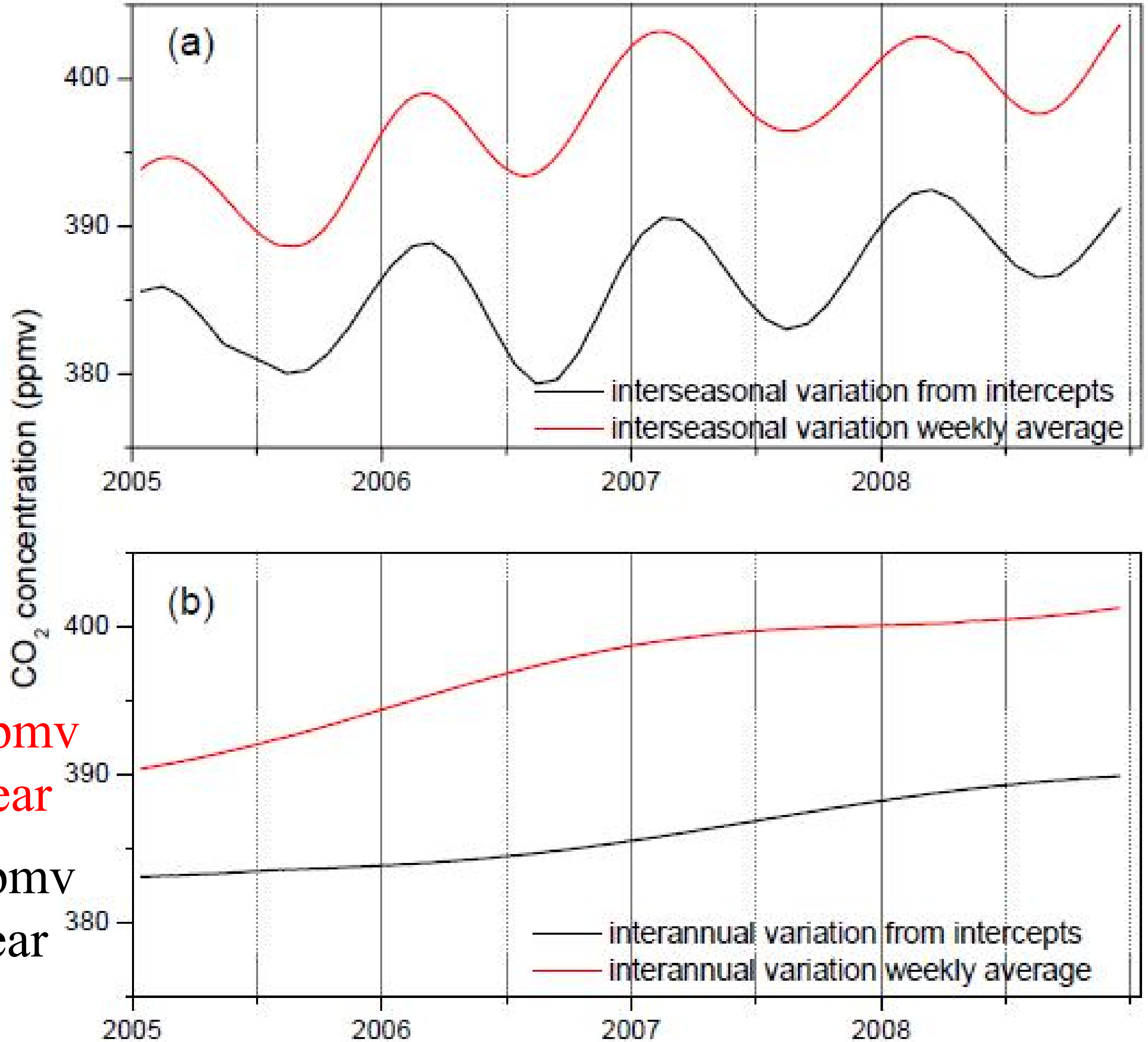


Fig. 7b. Background CO (b) derived at Miyun (green) compared to three ESRL sites (WLG, UUM, and TAP).

Results and discussion



2.7 ppmv per year

1.7 ppmv per year

Fig. 8. The interseasonal (a) and annual (b) variations of CO_2 observed at Miyun (red) and background CO_2 (black) derived from the CO_2-CO correlation analysis.

Results and discussion

Interannual variations in CO_2/CO ratio in winter

- Initial evaluation

Table 3. The CO_2-CO correlation slope (dCO_2/dCO) and trend for winter observations at Miyun.

	Overall data[3]		CO-filtered data[2]		NCN air masses[3] (CO filtered)	
Winter[1]	slope	error	slope	error	slope	error
2004	13.3	0.4	17.1	0.5	17.3	0.6
2005	21.8	0.4	23.5	0.6	23.8	0.9
2006	20.7	0.5	26.1	0.8	26.0	1.0
2007	25.7	0.4	27.7	0.8	28.6	1.1
2008	21.2	0.6	26.8	0.8	26.6	0.9
Change in mean slope from 2005–2006 and to 2007–2008	2.2 ± 0.5		2.5 ± 0.8		2.8 ± 0.9	

1.6....

2.61 ppmv/ppmv per year

1 Winter refers to a period of three months

2 The CO-filtered dataset refer to the data with CO levels between the 30th–90th percentiles.

3 CO_2-CO scatter plots for the overall data and for the NCN air masses are shown in supplementary material S.2 and S.3 respectively.

Results and discussion

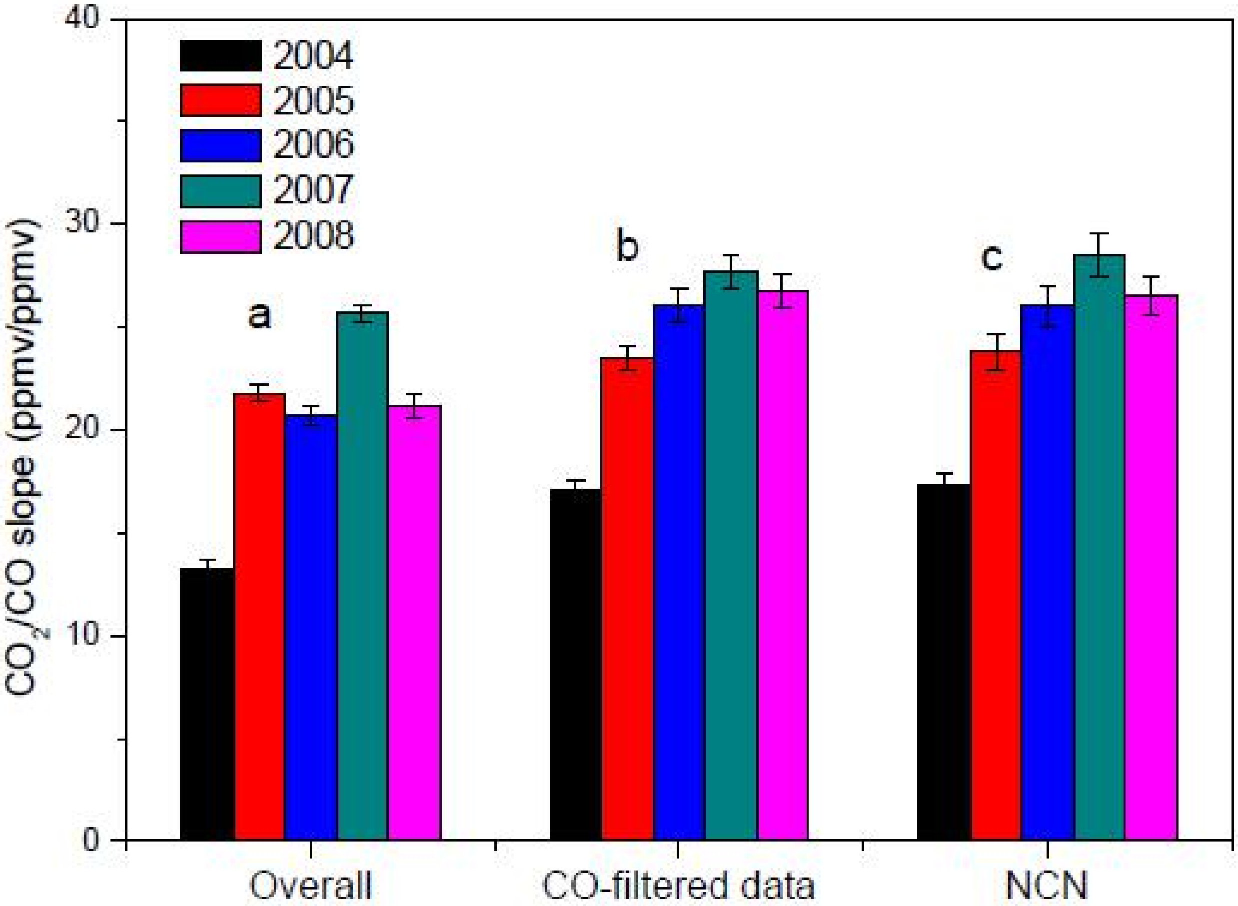


Fig. 9. The CO_2-CO correlationship slope (dCO_2/dCO) for winter observations at Miyun. The slopes are evaluated for the overall dataset (a), the CO-filtered dataset (with CO between the 30th and 90th percentiles) (b), and the CO-filtered northern China air masses (NCN) (c).

Results and discussion

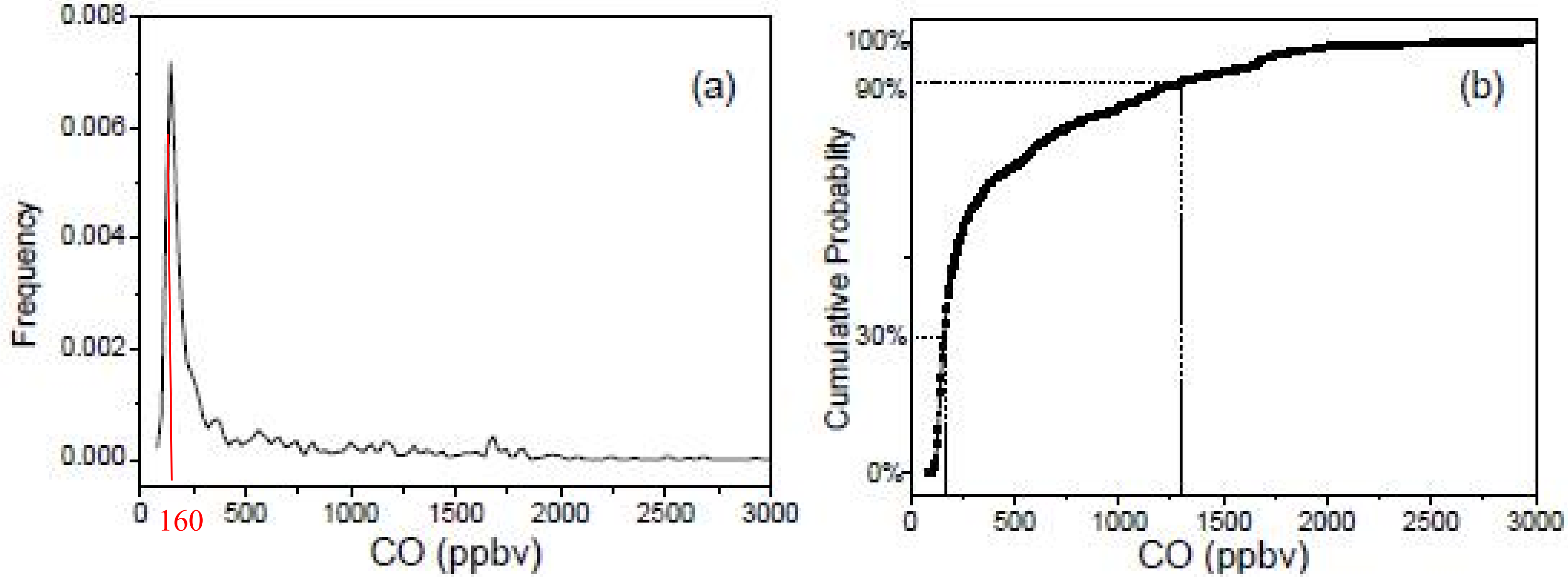


Fig. 10. Histogram (a) and cumulative probability distribution (b) of daytime CO mixing ratios in winter 2007 .

Results and discussion

- Air mass groups using cluster analysis

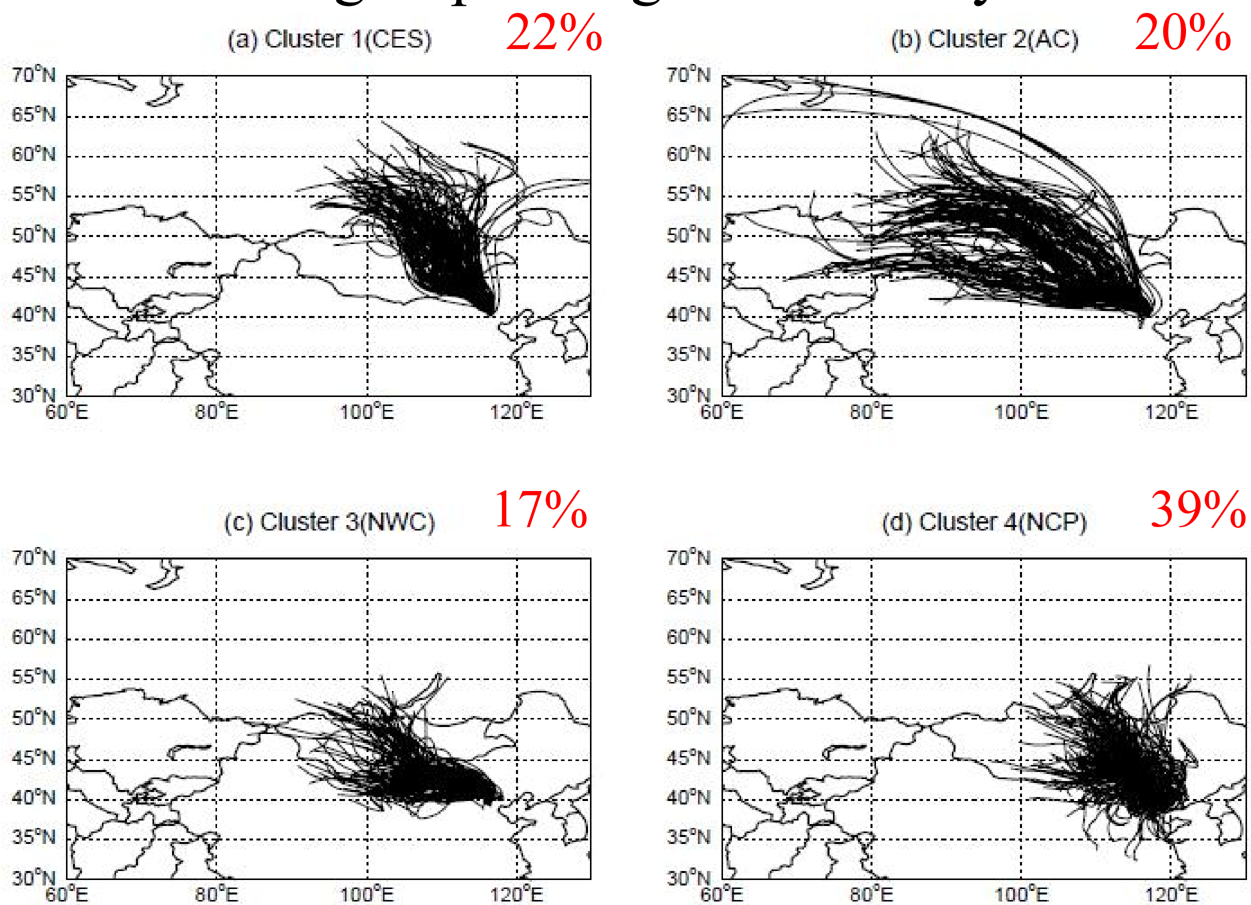


Fig. 11. Back trajectories for wintertime observations at Miyun (2004–2008) by clusters: Central East Siberia (CES) (a), Aged Continental (AC) (b), Northwest China (NWC) (c), and North China Plain (NCP) (d).

Results and discussion

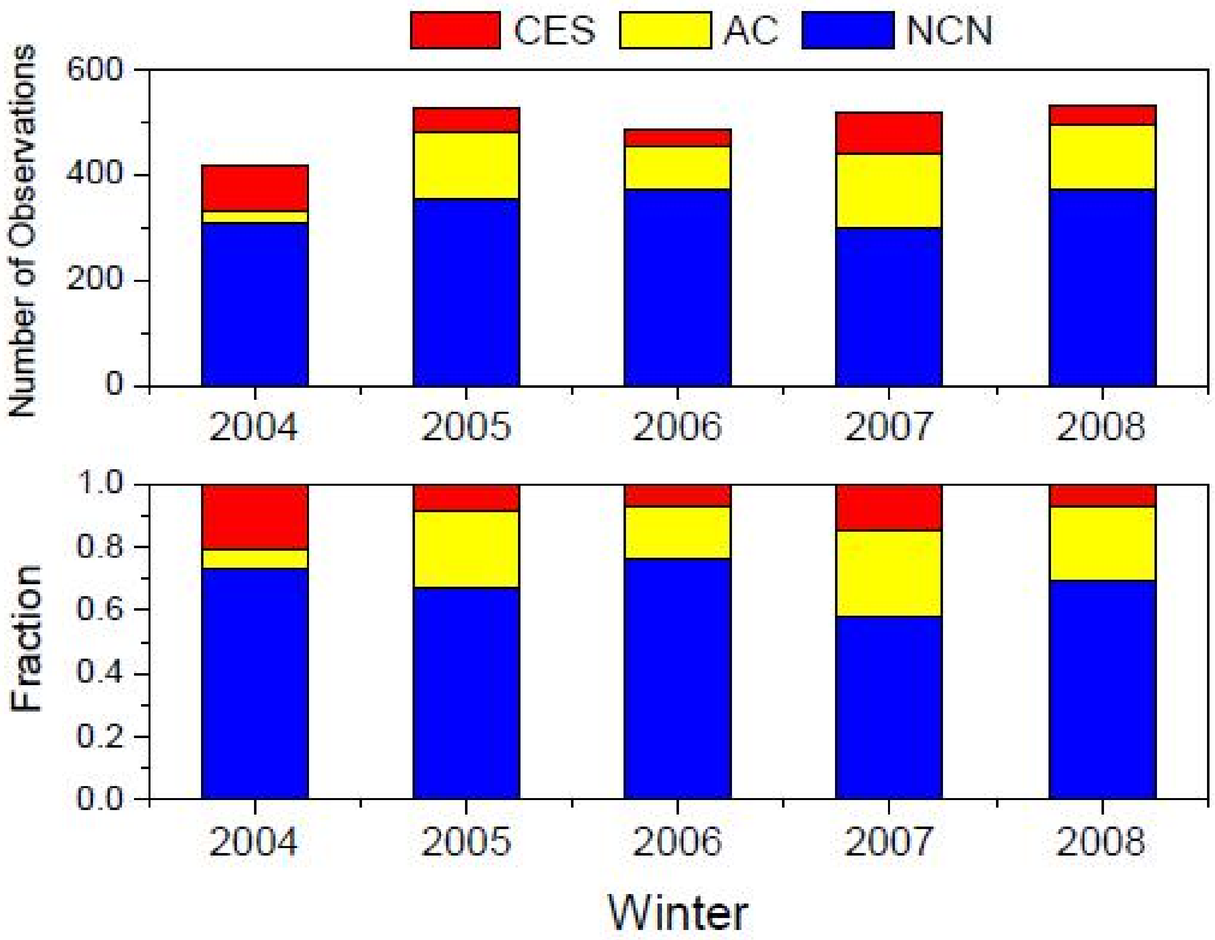


Fig. 12. (a) The number of observations in each winter by clusters;
(b) The fraction of each cluster in total observations in each winter

Results and discussion

Table 4. Mean CO_2, CO, and their relationship for each air mass group (CO-filtered) over the five winters (2004–2008).

Cluster	Share (%)	Mean CO_2 (ppmv)	Mean CO (ppmv)	Intercept (ppmv)	Slope (ppmv /ppmv)	R
CES	12	392.4	284.5	383.1±3.7	33.1±4.6	0.79
AC	19	396.3	496.6	385.0±2.2	23.0±6.7	0.93
NCN	69	400.2	666.1	384.2±3.5	24.4±4.4	0.94

Results and discussion

- CO_2/CO ratio for NCN air masses

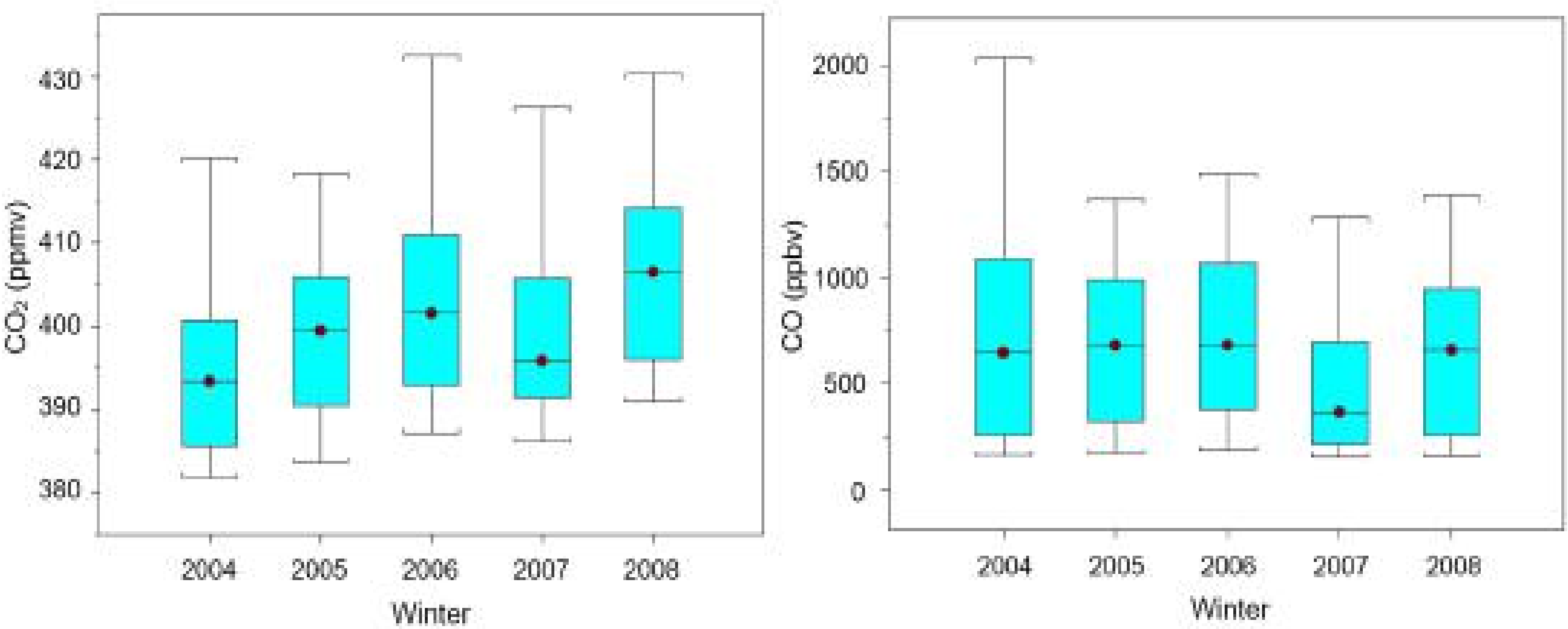


Fig. 13. Box plots of CO_2 (a) and CO (b) observations for the NCN air mass group at Miyun in winter, 2004–2008.

Results and discussion

Case study

Table 5. Mean CO_2 and CO mixing ratio and their correlations for September 2005–2008.

		2005	2006	2007	2008
CO (ppbv)	Mean	586.80	482.14	615.10	385.25
	Median	450.52	441.49	566.09	303.03
	25-percentile	124.55	180.27	309.22	179.68
	75-percentile	821.15	640.87	813.32	553.13
CO2 (ppmv)	Mean	390.01	386.82	395.76	397.41
	Median	389.33	386.05	394.02	397.12
	25-percentile	381.81	377.63	385.85	385.94
	75-percentile	396.80	394.7	402.78	407.18
dCO_2/dCO (ppmv/ppmv)		23.9 ± 8.4	27.7 ± 10.0	28.8 ± 5.6	46.4 ± 4.6
R		0.84 ± 0.05	0.65 ± 0.11	0.56 ± 0.14	0.76 ± 0.06

Results and discussion

Table 6. dCO_2/dCO for October, November, and December, 2005–2008.

dCO_2/dCO (ppmv/ppmv)	Oct	Nov	Dec
Average for 2005-2007	24.8±4.3	21.5±5.2	23.2±2.4
2008	38.7±5.5	30.9±2.7	29.6±1.4

Conclusions

- Compared with CO_2 mixing ratios reported by ESRL for background sites at similar latitudes, monthly mean CO_2 mixing ratios at Miyun are 10 ppmv higher on average and exhibit irregular seasonal cycles, reflecting influence from local and regional sources and sinks.
- Annual growth of overall mean CO_2 is increasing by 2.7 ppmyr−1 while $CO_{2,b}$ is only increasing by 1.7 ppm yr−1 suggesting relatively faster increase in the regional CO_2 sources in northern China than the global average.
- For NCN air masses, mean winter CO_2/CO correlation slopes (dCO_2/dCO) increased by 2.8±0.9 ppmv/ppmv or 11% from 2005–2006 to 2007–2008 which indicates improvement in overall combustion efficiency over northern China after winter 2007, attributed to pollution reduction measures associated with the 2008 Beijing Olympics.
- The observed CO_2/CO ratio at Miyun is 25% higher than the bottom-up CO_2/CO emission ratio, suggesting a contribution of respired CO_2 from urban residents as well as agricultural soils and livestock in the observations and uncertainty in the emission estimates.

Thanks for your listening !