SEASONAL VARIATION OF PHOTOCHEMICAL SMOG POLLUTION IN METROPOLITAN CITY OF INDIA IN RELATION TO OZONE PRECURSOR CONCENTRATIONS AND METEOROLOGICAL CONDITIONS

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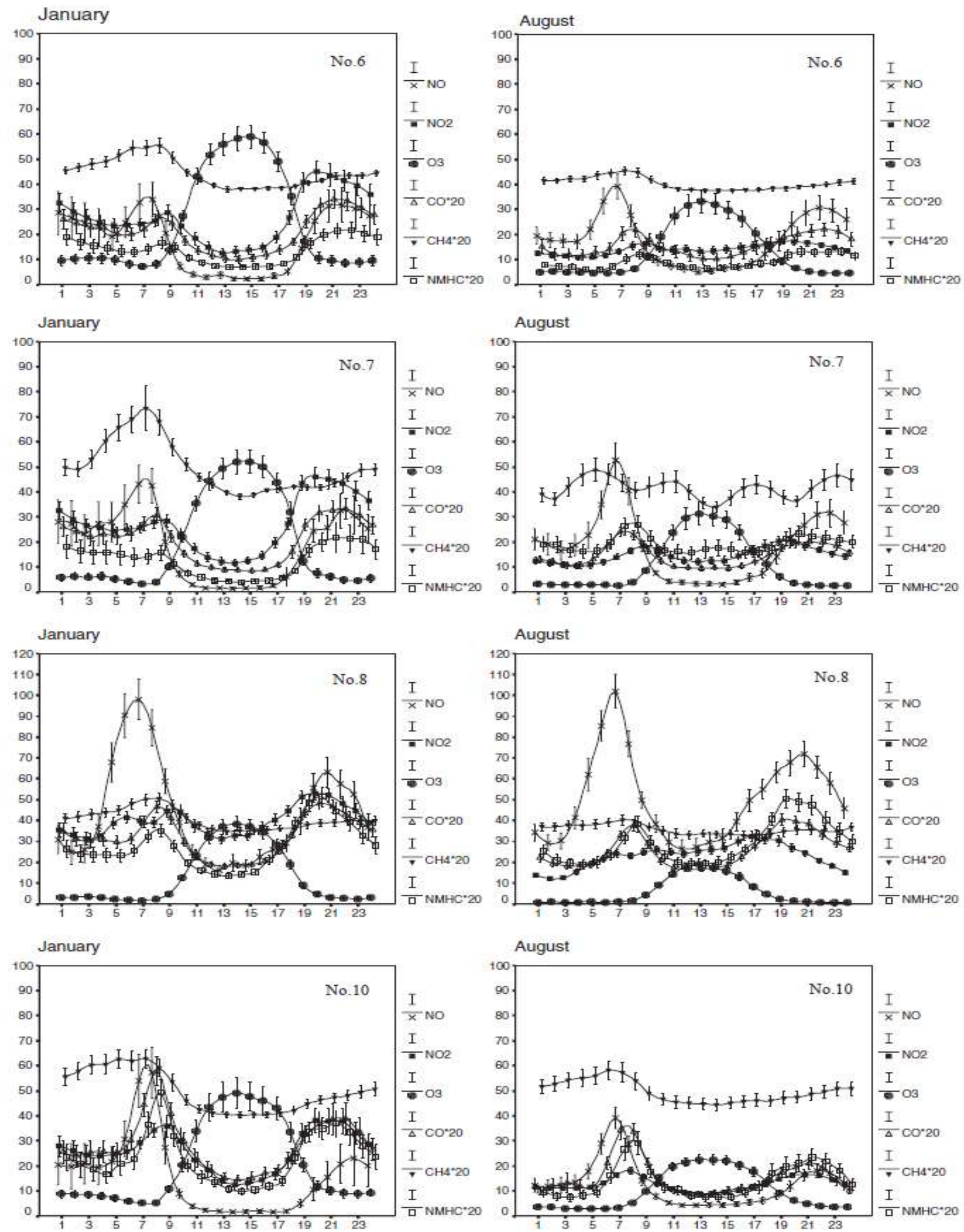
HIGHLIGHTS

Common Aim:

- Photochemical Pollutants status during 2009-10 by taking different seasons in Delhi, India.
- Complementary research questions???

- Why Photochemical Pollutants?
- How meteorological parameters affect photochemical smog pollution?
- Why it is an important topic for photochemical smog modellers?

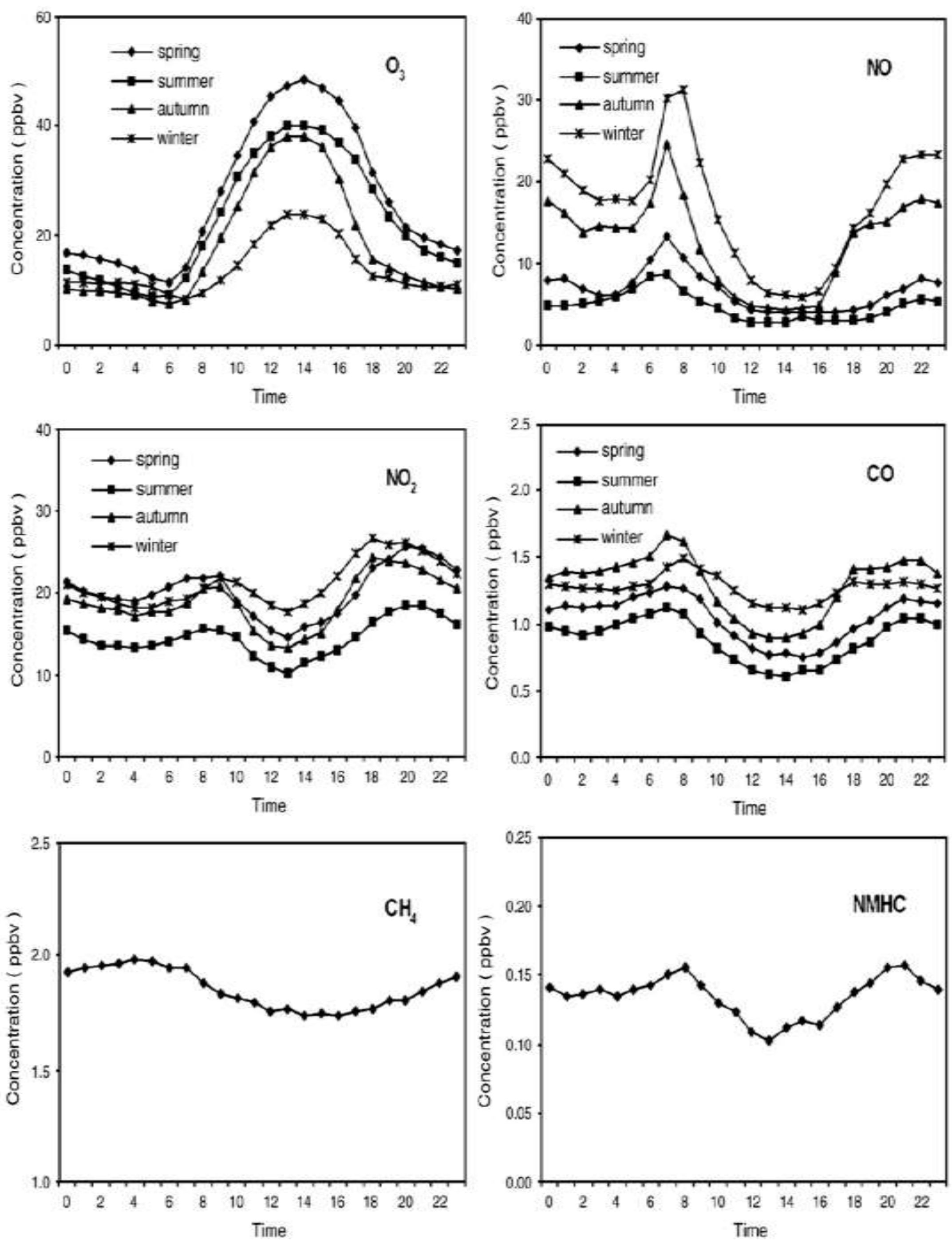
Diurnal variations of photochemical pollution precursors, NO, NO_2, CO, NMHC, and CH_4, and O_3 for the selected stations (6, 7, 8 and 10) for each month were analyzed at Bangkok, Thailand. January (with high O_3) and August (with minimum O_3) data for the stations are presented. Source: Zhang and Oanh, 2002, Atmos. Env. 36: 4211-4222.



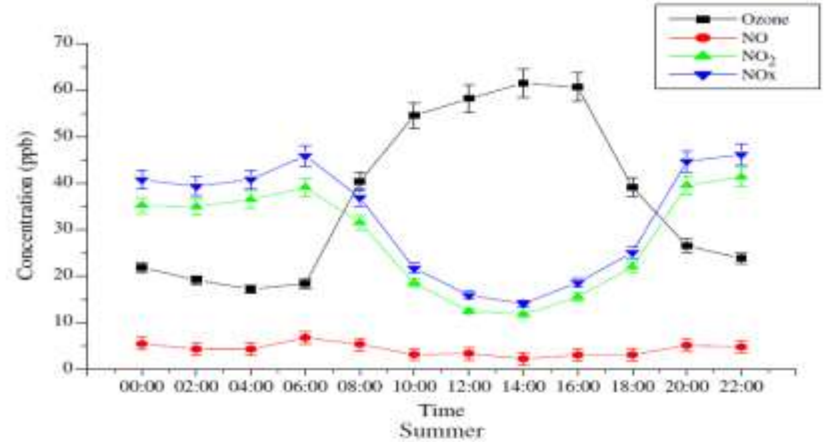
✓Average diurnal variations of O3, NO, NO_2, CO, CH_4 and NMHC in different seasons for the period from January 2000 to February 2003 in Nanjing.

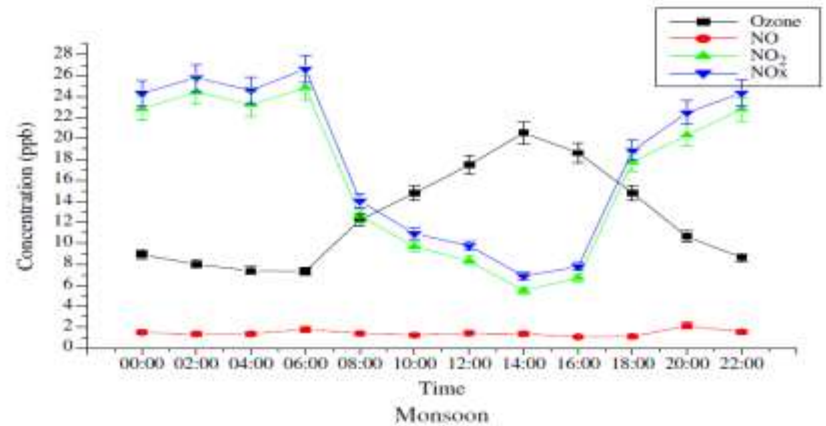
✓The amplitude, which is the difference in O_3 concentration between daytime and nighttime, is the highest in spring, the second highest in summer, the third highest in autumn, and the lowest in winter.

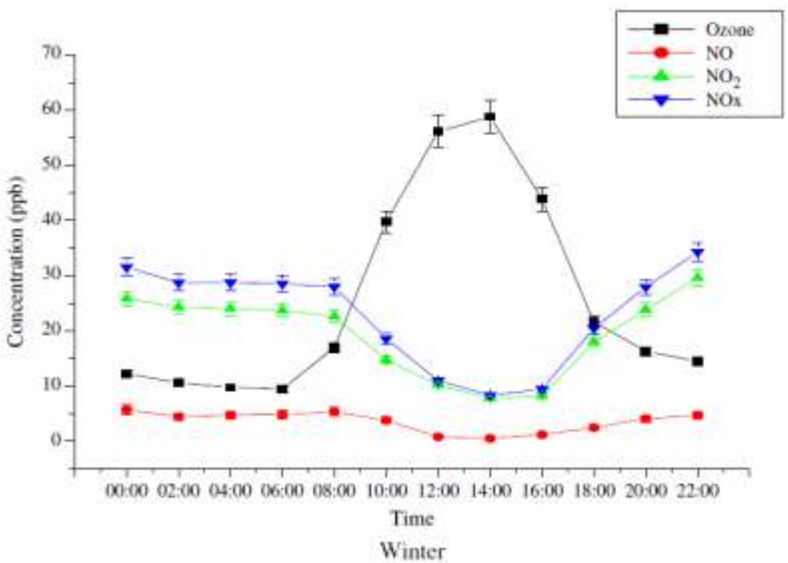
✓The diurnal variations of the precursors for the four seasons show a similar pattern; however, the hourly concentrations and/or amplitudes of the diurnal variations show significant differences among seasons ($p<0.001$). Source: Tu et al., 2007, Atmos. Res. 85: 310-337.

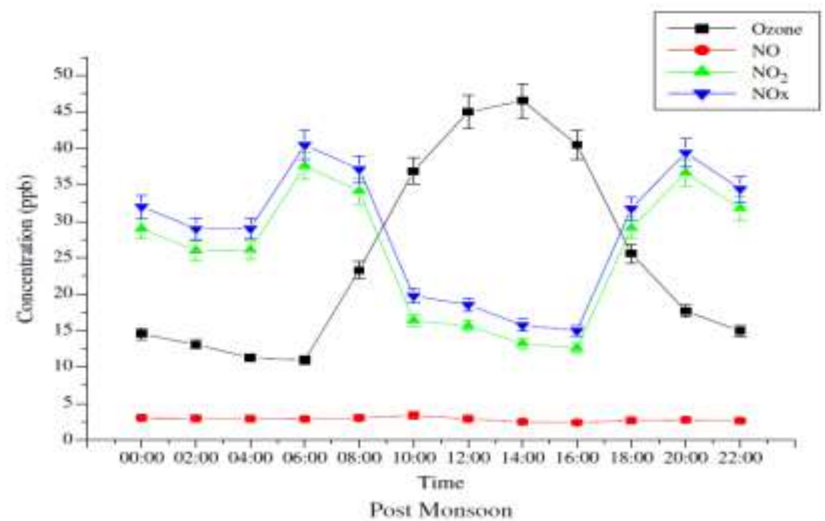


Strong diurnal variation is observed in all the four seasons viz. winter, summer, monsoon and post-monsoon with the daytime values almost 3 times the nocturnal values except in the monsoon season at Agra. Source: Singhla et al. 2011, Atmos. Res. 101: 373-385.

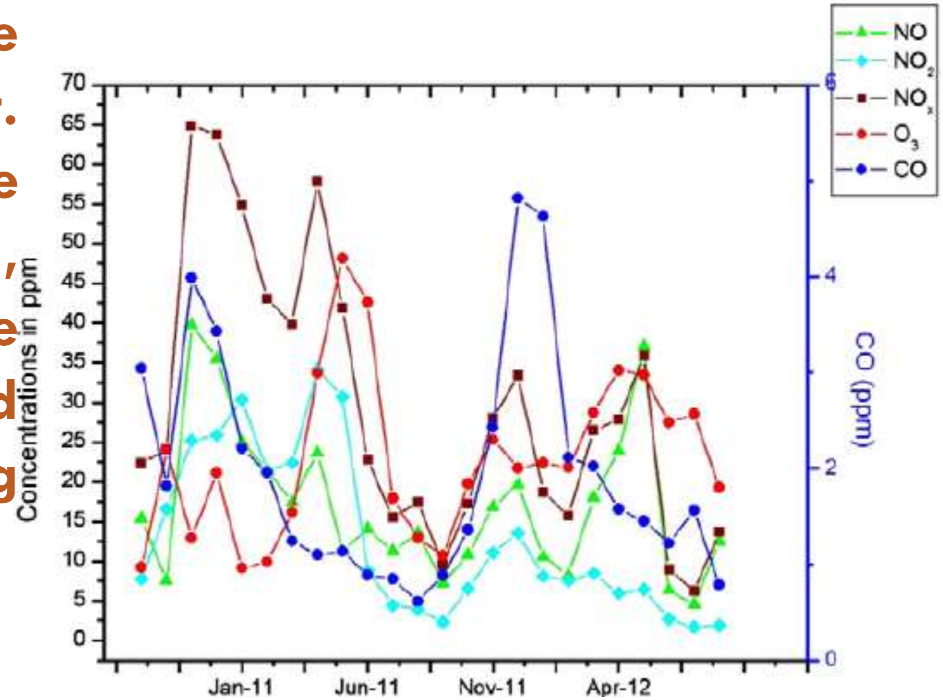








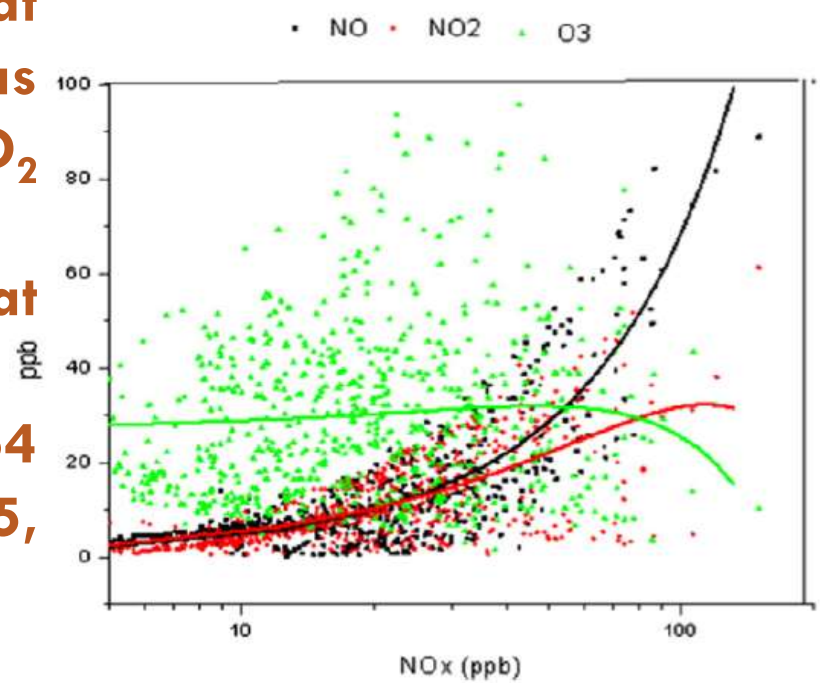
The concentrations of ozone increased to a significant extent. This is consistent with the increase in the number of vehicles on road, which corresponds to the increasing levels of NOx and VOCs as a result of increasing vehicular emissions in Delhi.



Ozone concentrations fall rapidly at higher NOx concentrations, whereas the concentrations of NO and NO_2 rise with increasing NOx levels.

- NO dominates over NO_2 and O_3 at higher NOx concentrations.

O_3 and NO curves crossover at 54 ppb NOx. Source: Tiwari et al. 2015, Atmos. Res. 157: 119-126.

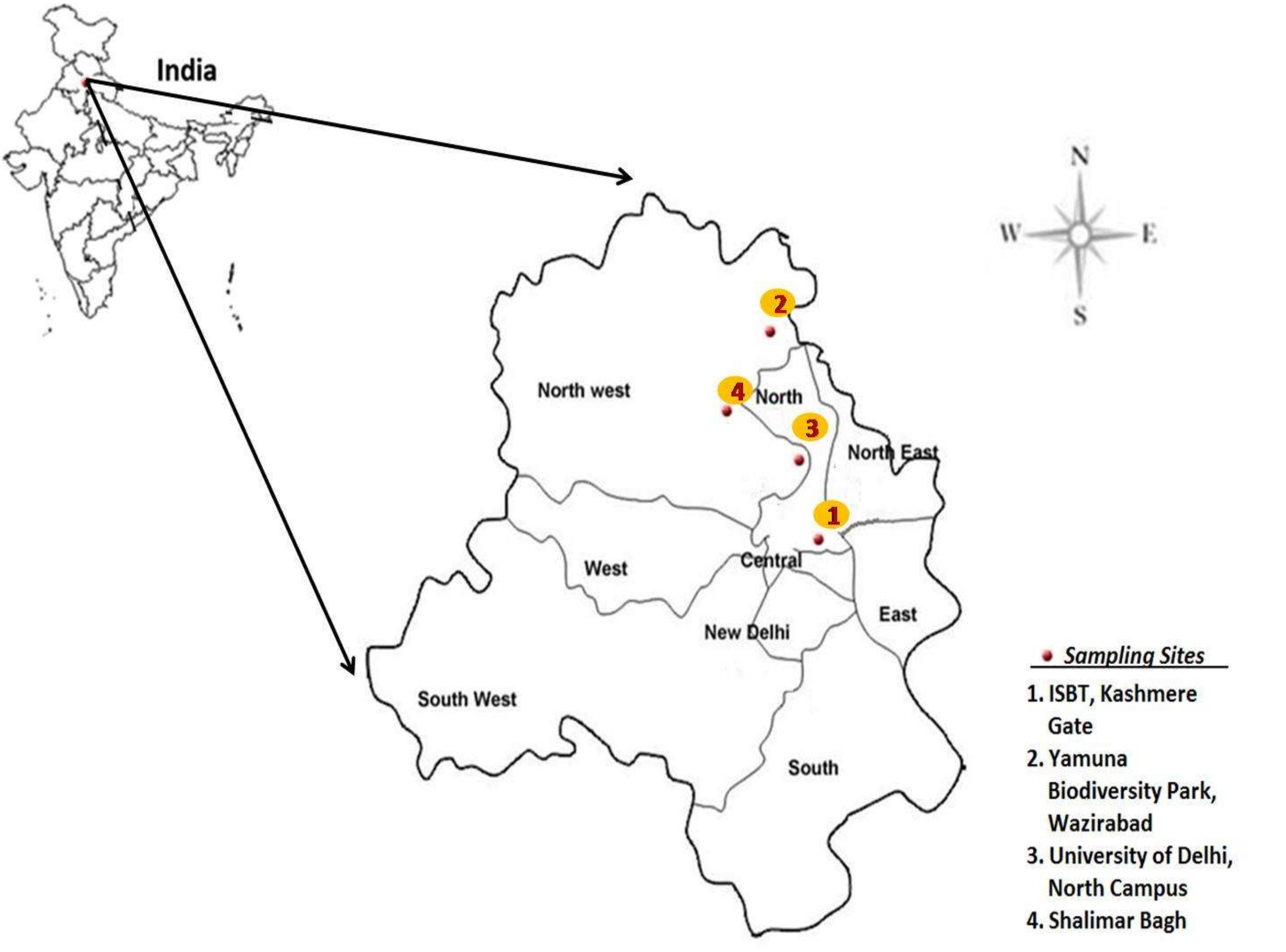


RATIONALE OF STUDY

- Lack of systematic monitoring data of ozone and its precursors mostly in Asian countries.
- Very less studies have been reported so far on photochemical pollutants in most of the developing Asian countries.
- Studies related to monitoring data of photochemical pollutants sets up a platform for photochemical smog modellers.

OBJECTIVES

- Ozone pollution status and trend in New Delhi, India during three different seasons viz. summer, monsoon and winter from year 2009-2010.
- Average monthly and diurnal variations of ozone are analyzed in connection with O_3 precursors i.e. photochemical pollutants and meteorological conditions.
- To estimate the effective NOx/NMHC ratio for production of O_3, and seasonal variations in NOx/NMHC ratios are analyzed to assess the seasonal photochemical smog potentials.


India
N
W
E
S
2
4
North west
North
3
North East
1
West
Central
East
New Delhi
South West
South
Sampling Sites
1. ISBT, Kashmere Gate
2. Yamuna Biodiversity Park, Wazirabad
3. University of Delhi, North Campus
4. Shalimar Bagh

Parameters Under Study

A. Measurement of pollutant concentration:

NO_2 : using NOx analyzer, Thermofischer

O_3 : using O_3 analyzer, Environment S.A.

NMHCs : THC analyzer, Thermofischer

B. Meteorological Parameters:

Secondary data from IMD.

Sampling Pattern

Sampling Pattern: Samples were collected during three seasons viz. summer (Apr-Jun), monsoon (July-Sept) and winter (Nov-Feb).

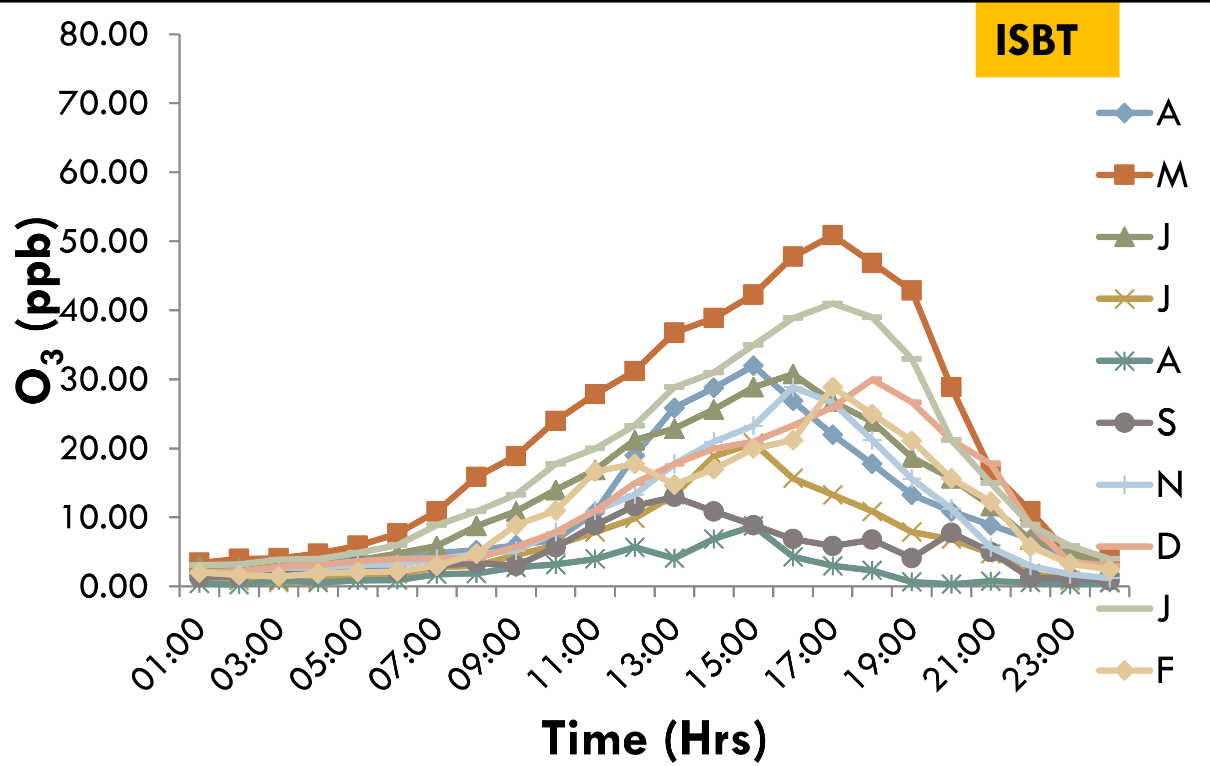
Data Matrix: 4 sites x 3 seasons x 3 parameters

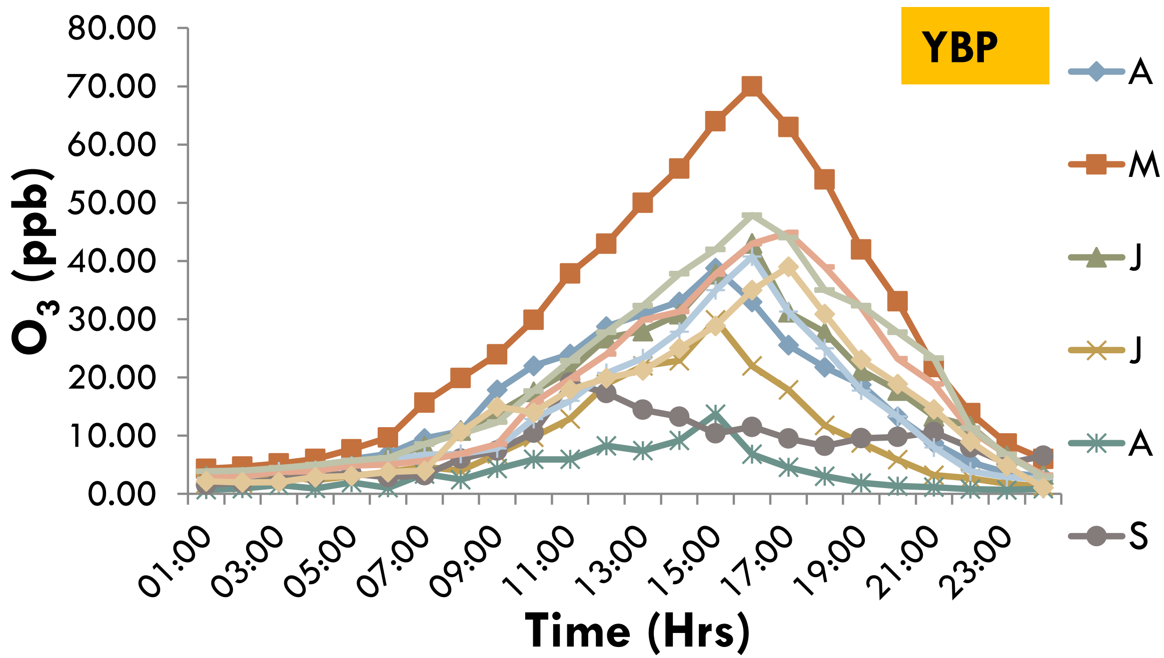
Statistical Analysis

- **Pearson's Correlation**

Software Package Used: SPSS (19.0 version)

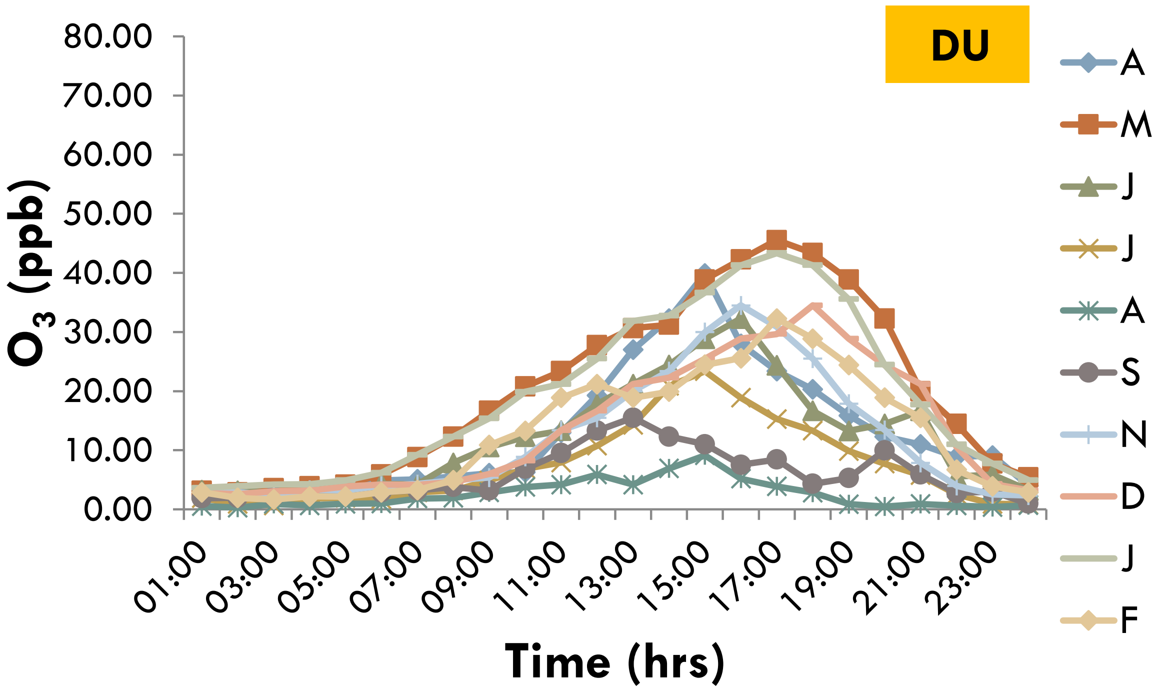
- ➢HighO_3 concentrations were found at away from traffic intersection site (YBP) reflect the dispersion of O_3 and its precursors as compared to other sites.
- ➢Interestingly, near to traffic intersection site (ISBT), relatively low O_3 was found as compared to away from traffic intersection site (YBP) may be due to O_3 destruction by NO in the NO_2 photolytic cycle.

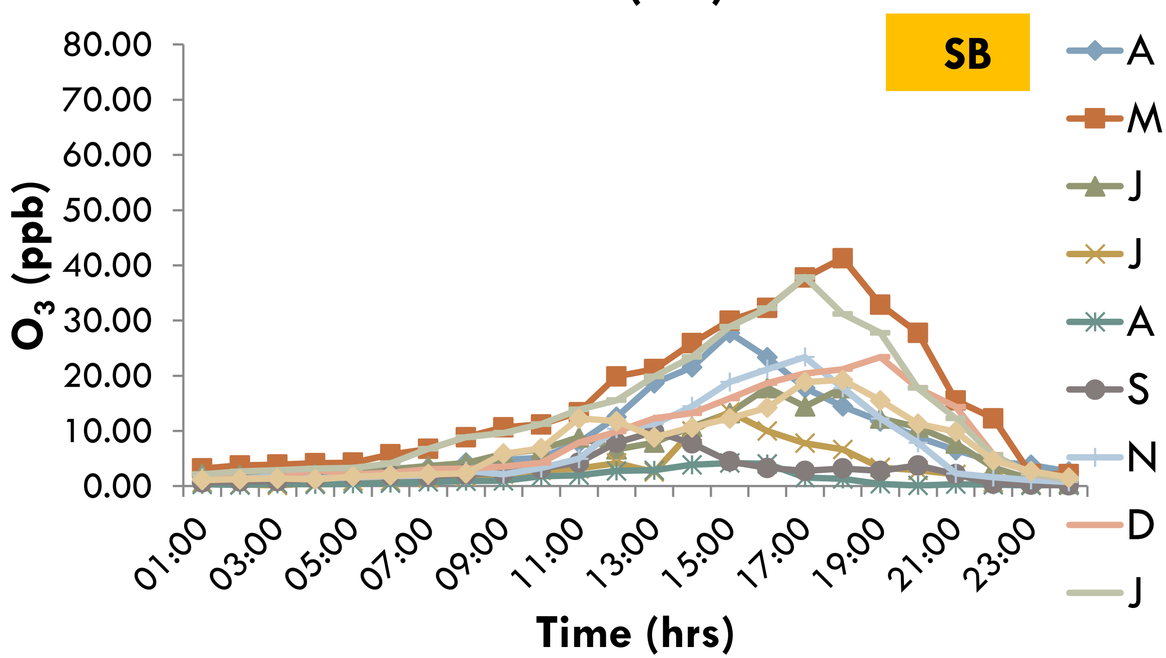


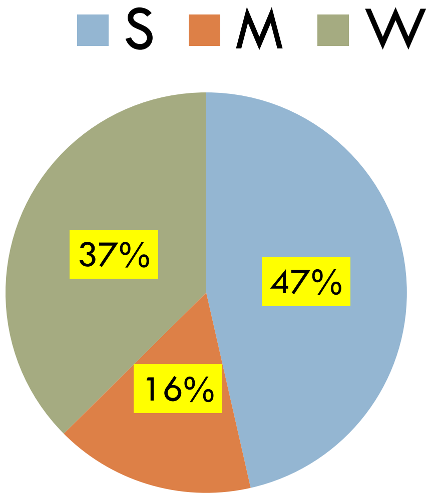


➢O_3 levels generally increasing from 13:00 till 15:00 and showed decreasing levels from 18:00 hrs at all the sites due to its high photochemical activity during that time and also the influence of meteorological parameters like comparatively high temperature and low wind speed during the time period of 13:00 – 15:00.

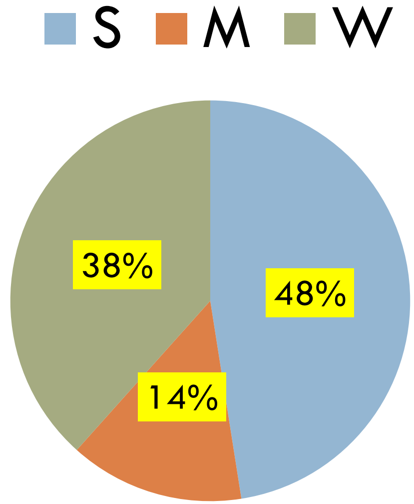
➢Highest hourly concentration of O_3 was found to be 69.93 ppb which is crossing the permissible limit 40 ppb for O_3 in case of plants by NCLAN and nearby to NAAQS CPCB permissible limit.





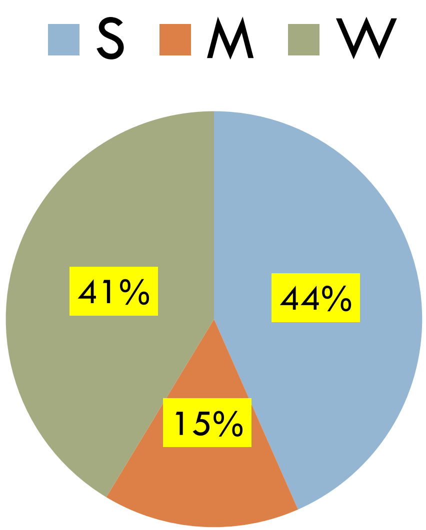


ISBT

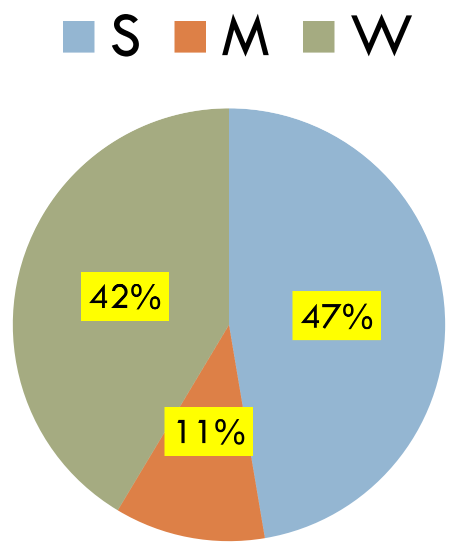


YBP

- **Lowest percentage contribution of ozone was found in monsoon. Aqueous reactions in clouds consume radicals or effects of vertical mixing, wet deposition of soluble O3 precursors, decrease in solar radiation and decrease in temperature.**
- **Highest O_3 average of hours of O_3 exceeding 40 ppb was found to at all the sites except residential site.**



DU



SB

Sites	Total Hours	Total Days	Max. O_3 (ppb)
1	8	3	**78.65**
2	4	2	58.89
3	2	1	48.87
4	-	-	-

Comparison of Monthly Mean Meteorological Data of Delhi (Source: IMD, Delhi)

Months	Temp. (°C)	Rel. Humidity (%)	Wind Speed (m/s)	Solar Radiation (MJ/m2)	Rainfall (mm)
April	39	43	1.3	23.67	2.0
May	43	40	1.2	28.76	4.3
June	40	47	2.5	24.11	5.4
July	37	74	4.2	19.5	124.2
August	33	81	7.8	17.5	188.6
September	32	78	6.1	14.8	201.9
October	28	60	3.4	15.9	0.3
November	23	62	2.3	12.76	14.2
December	14	64	1.8	11.65	1.0
January	11	68	1.4	10.65	0.0
February	20	65	3.6	13.87	14.2

Correlation between O_3 and meteorological variables

Meteorological Variables	Karl Pearson's Correlations		
	Summer (n = 730)	Monsoon (n = 689)	Winter (n = 1017)
T_{max}	0.764**	-0.020	0.532**
DP_{avg}	-0.067	0.476*	-0.011*
RH_{avg}	-0.608**	0.473*	-0.726**
SR_{avg}	0.692*	0.082*	-0.428**
WS_{avg}	-0.465	-0.060	0.355
NMHCs avg.	-0.690**	-0.598*	-0.677**
NO_2 avg.	- 0.566*	- 0.577*	- 0.774**

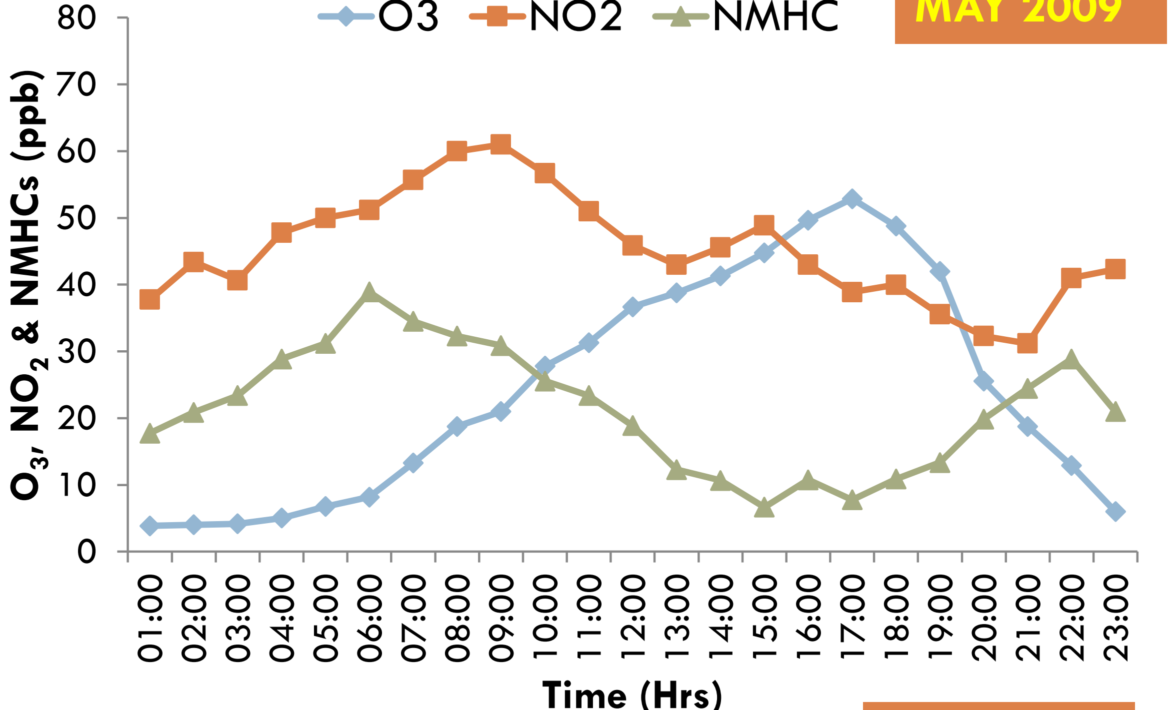
*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

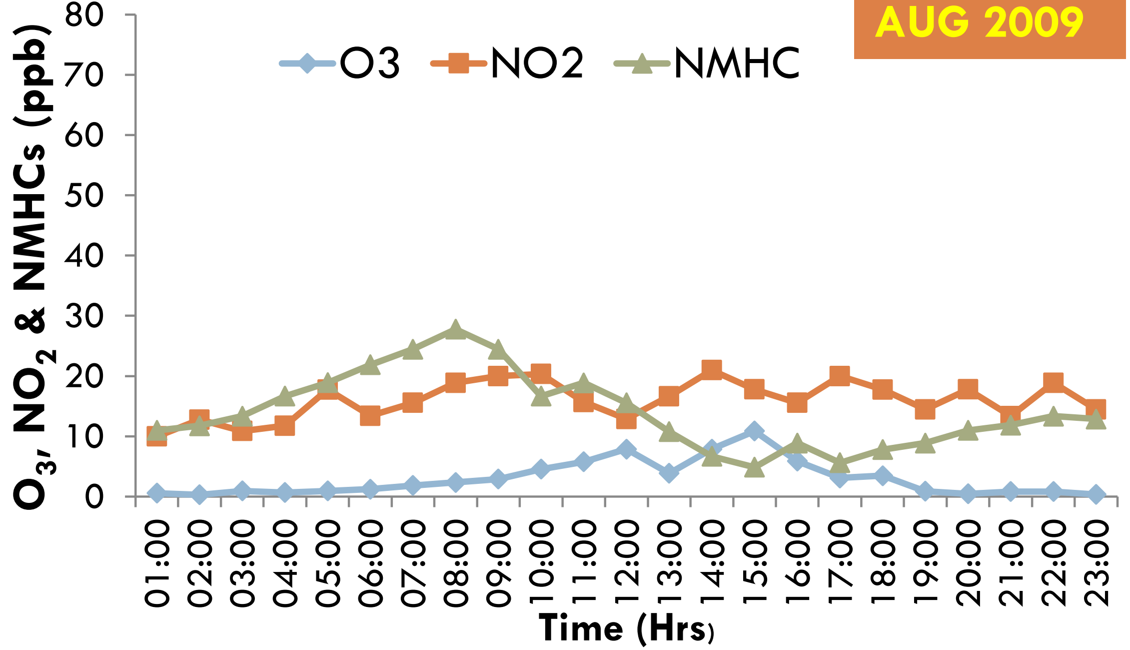
Site 1: ISBT

- In the early morning rush hours (around 7:00-8:00 a.m.) the NMHCs concentrations were found to be high.
- NO_2 peaks at around 9:00 a.m. starts increasing which reflects the time taken for conversion of NO to NO_2 involving HC.
- O_3 concentration also starts increasing after sunrise i.e. around 8:00 am. Onwards and reached to its peak in between 13:00 – 15:00 hrs.

MAY 2009

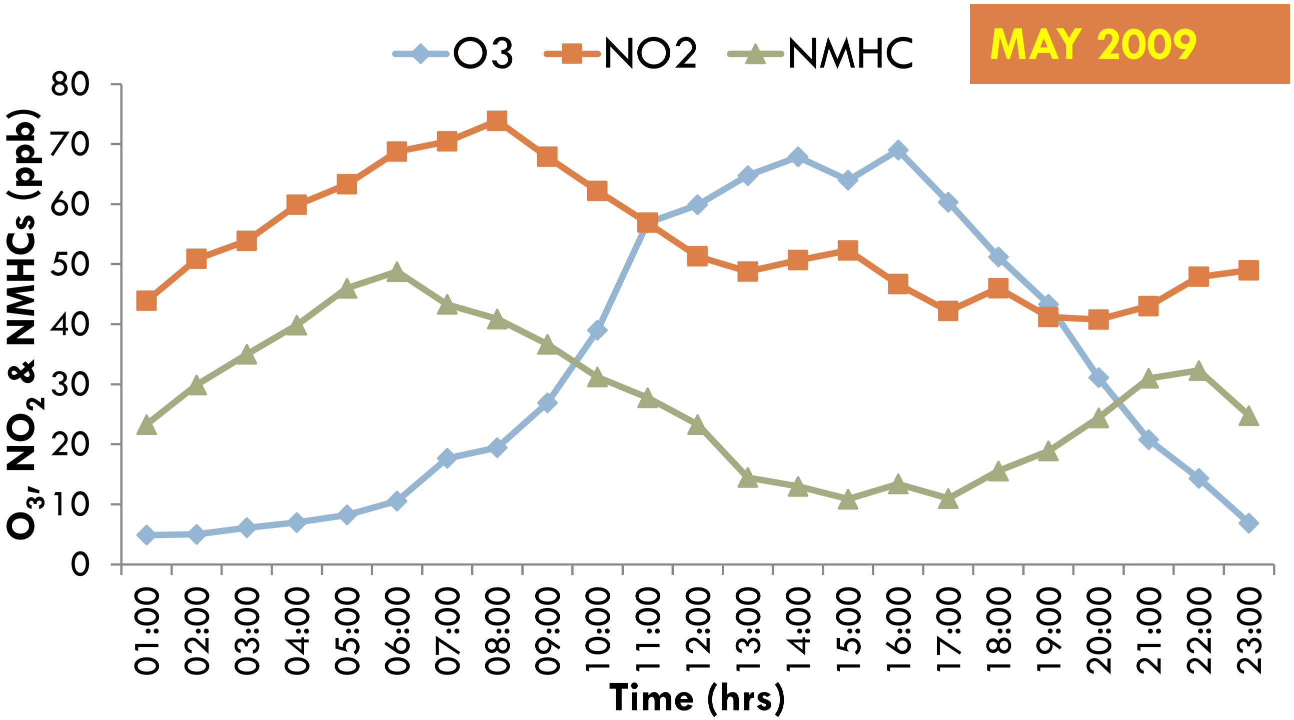


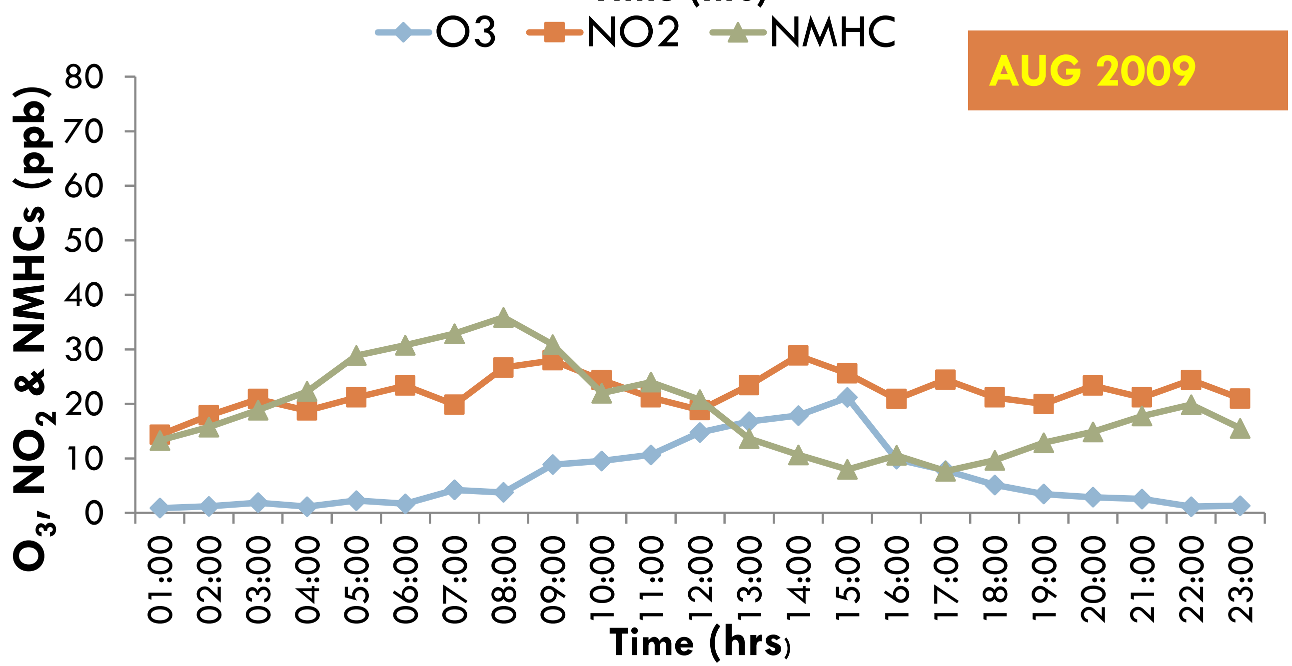
AUG 2009



Site 2: YBP

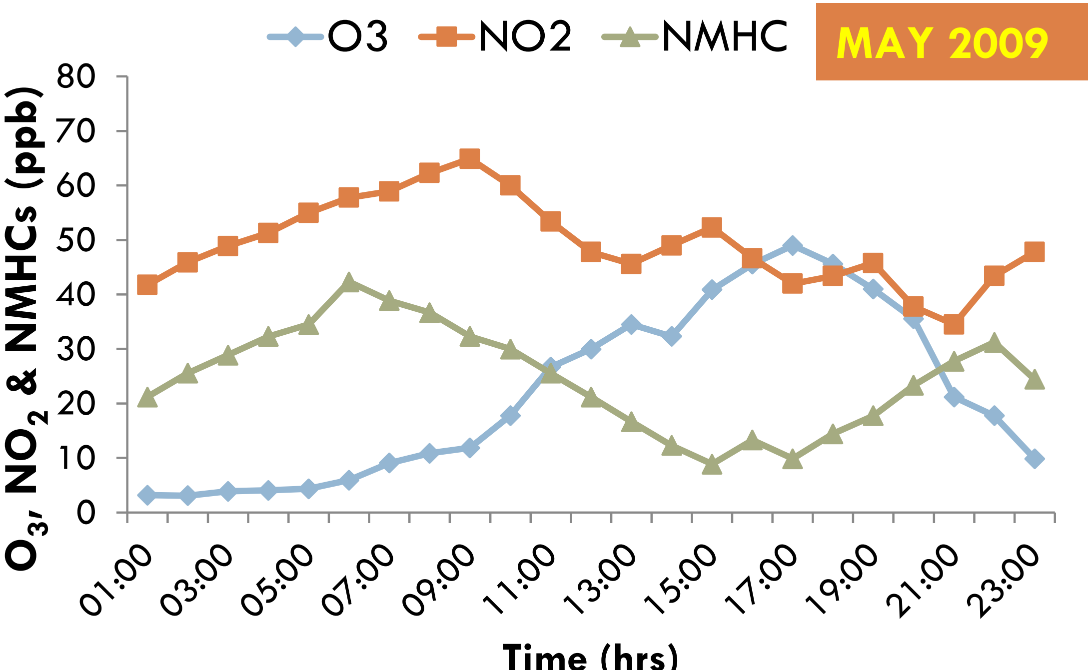
- Among all the months of selected seasons i.e. summer, monsoon and winter, May had reported highest and August lowest O_3 hourly averaged concentrations at all sites.
- Photochemical destruction of O_3 by NO in the NO_2 photolytic cycle and also high OH radical activity during the month of August.

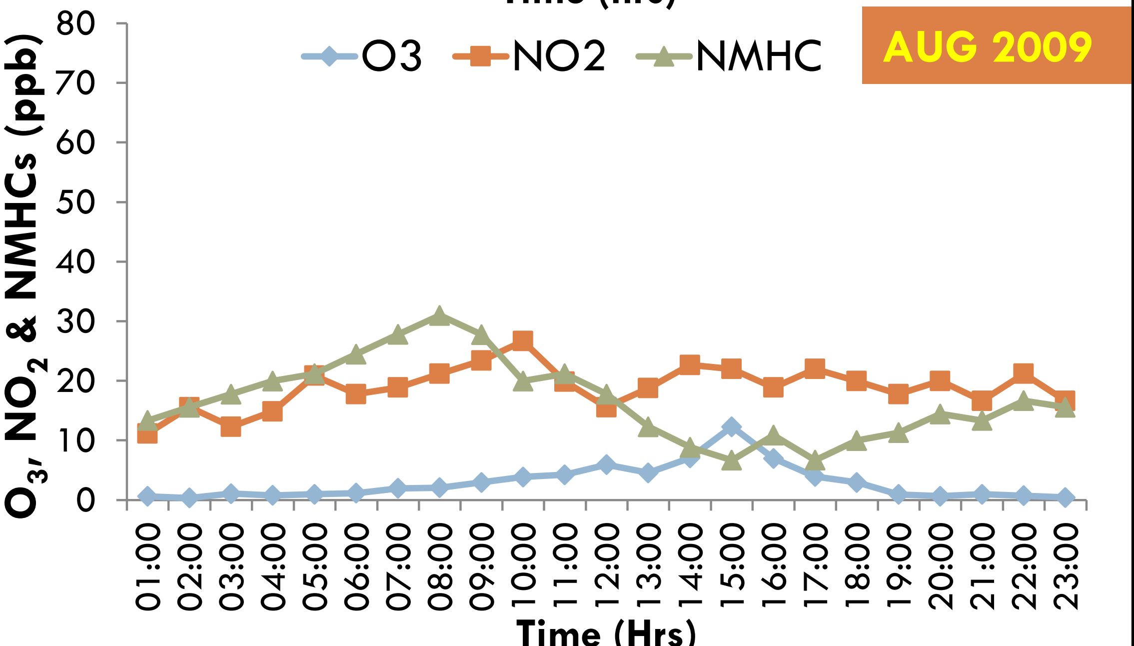




Site 3: DU

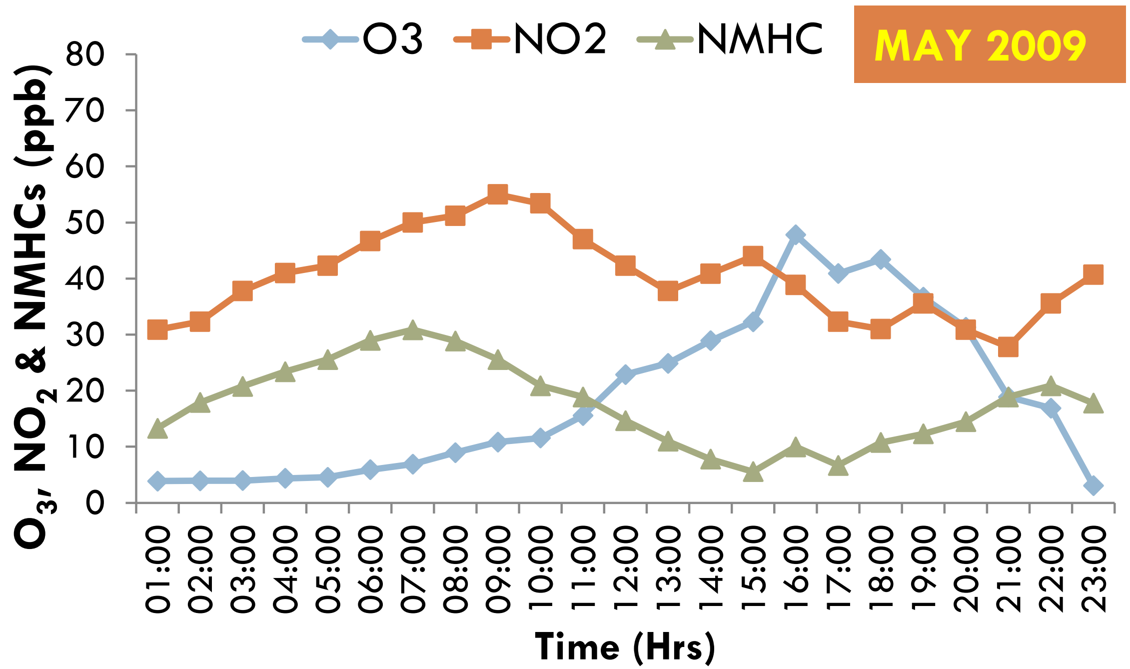
- No significant change has been observed in near to traffic intersection (ISBT) and institutional site (DU) in case of especially O_3. This is due to DU is also surrounded by commercial places, traffic congestion especially of two-wheelers and one traffic intersection area.
- O_3 found to be minimum in early morning may be due to high NO concentrations and lower solar radiation and temperature as compared to afternoon.

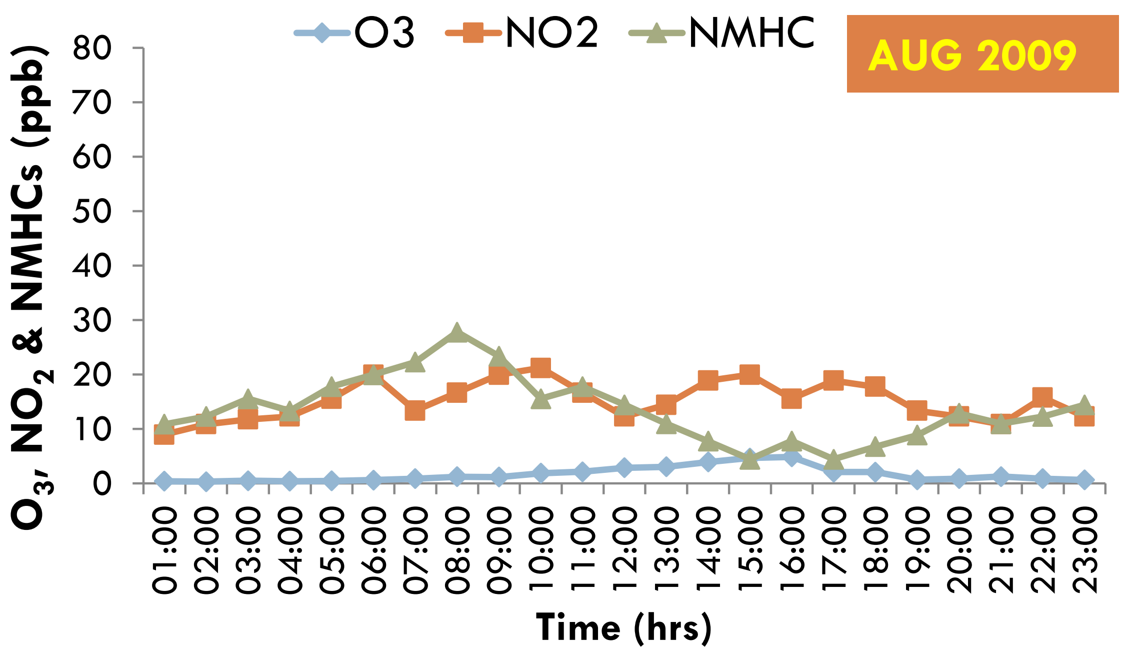


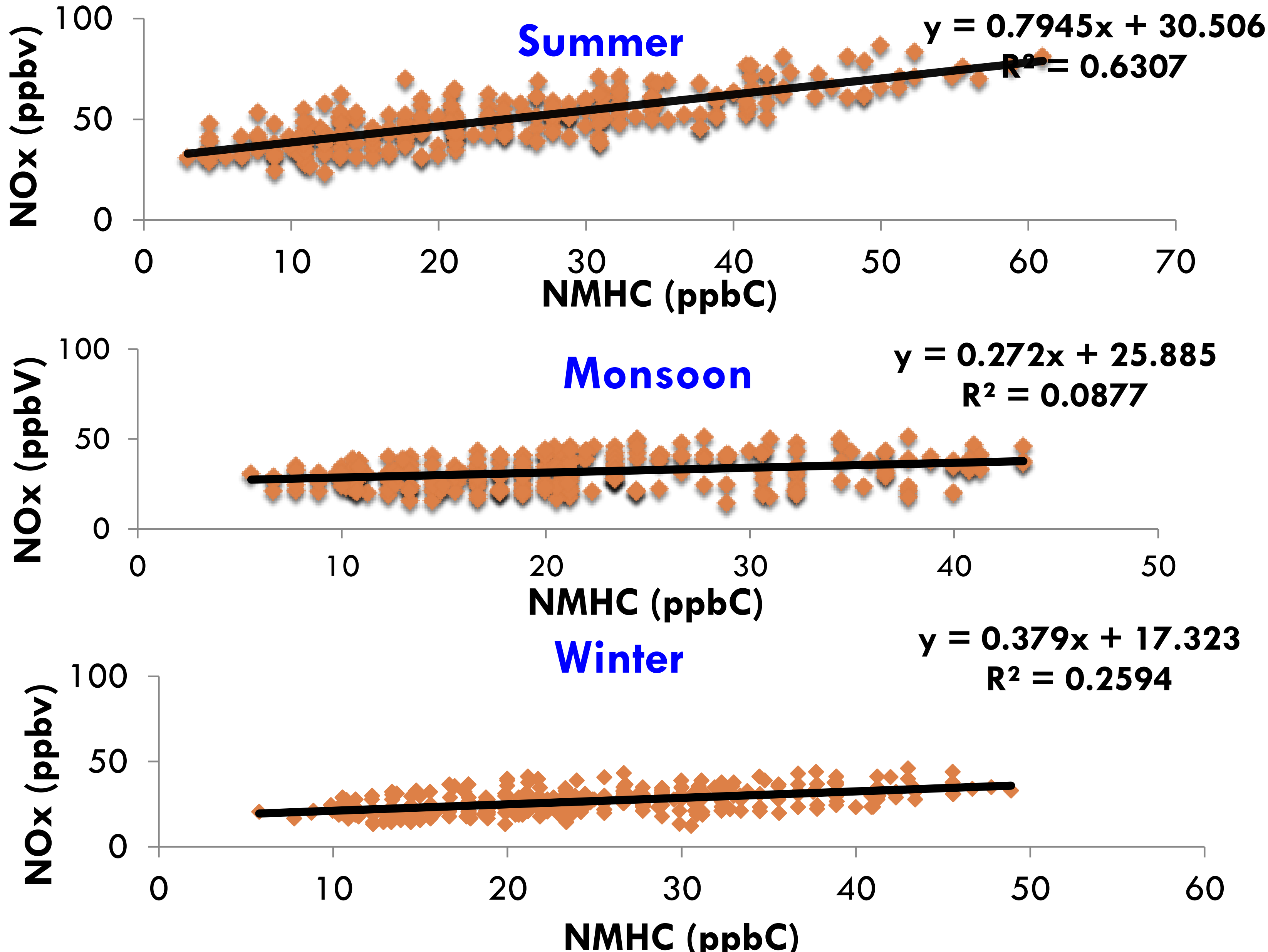


Site 4: SB

- **NMHCs concentrations were found to be low both in summer as well as monsoon months i.e. May and August because May is a summer month in which volatility rate is high which leads to evaporation.**







$NO_2 + O_3 \longrightarrow NO_3 + O_2$

$NO_3 + NO_2 + M \longrightarrow N_2O_5 + M$

$N_2O^5 + H_2O \longrightarrow 2HNO_3$

CONCLUSION

- Ozone formation and accumulation in Delhi reflects the interaction of local emission and photochemistry as well as the urban and regional transport of the pollutant and its precursors to study area.
- Photochemical smog potential in Delhi is high due to the high local emission of O_3 precursors and the favourable meteorological conditions like high temperature and low wind speed.
- The Asian monsoon with associated typical local meteorological conditions and the regional transport is the main factor causing the seasonal variations of O_3.
- Seasonal variations of NOx/NMHC ratios are showing more effective O_3 production in summer (0.79), followed by winter (0.37), and the lowest in monsoon season (0.27).

SUGGESTIONS/RECOMMENDATIONS

- Interactions of local emission and regional meteorological conditions in the formation and accumulation of O_3 are important for development of efficient and cost-effective O_3 pollution management strategies.
- Further studies are necessary to better understand the synoptic meteorological transport processes especially for high ozone days.

ACKNOWLEDGEMENT

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THANKS FOR THE ATTENTION