International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:5, 2011

An Investigation into Ozone Concentration at Urban and Rural Monitoring Stations in Malaysia

Negar Banan[a]*, Mohd Talib Latif[b]

***Abstract*—**This study investigated the relationship between urban and rural ozone concentrations and quantified the extent to which ambient rural conditions and the concentrations of other pollutants can be used to predict urban ozone concentrations. The study describes the variations of ozone in weekday and weekends as well as the daily maximum recorded at selected monitoring stations. The results showed that Putrajaya station had the highest concentrations of O_3 on weekend due the titration of NO during the weekday. Additionally, Jerantut had the lowest average concentration with a reading value high on Wednesdays. The comparisons of average and maximum concentrations of ozone for the three stations showed that the strongest significant correlation is recorded in Jerantut station with the value R^2= 0.769. Ozone concentrations originating from a neighbouring urban site form a better predictor to the urban ozone concentrations than widespread rural ozone at some levels of temporal averaging. It is found that in urban and rural of Malaysian peninsular, the concentration of ozone depends on the concentration of NOx and seasonal meteorological factors. The HYSPLIT Model (the northeast monsoon) showed that the wind direction can also influence the concentration of ozone in the atmosphere in the studied areas.

***Keywords*—**Ozone, Hysplit model, Weekend effect, Daily Average and Daily maximum, Malaysia

I. Introduction

OZONE is considered a secondary pollutant as it is a by product of the reaction. Under normal conditions, it will react with NO to form NO_2 and O_2. But since VOCs are more attracted to NO, the forward reaction is preferred, leading to the formation and accumulation of O_3. Ozone makes up an essential part of the atmosphere, especially the troposphere, the layer nearest to the Earth's surface. The major ozone sources in the atmosphere are the air mass exchange between the stratosphere and troposphere, in situ photochemical production or destruction and surface dry deposition [34]. The first source is a natural process where ozone is transported from the stratosphere to the troposphere. The influence of stratospheric-tropospheric ozone exchange has also been investigated as a possible cause of changes in the background ozone level [38]. The second source is the product of the anthropogenic precursor emissions, and contributes heavily to the amount of ozone in the troposphere globally. Debaje and Kakade [6] believe that the life cycle of O_3 in the lower troposphere depends on the season and the altitudes. It usually lies within the range of a few days (5-8) at the ground level to a few weeks (3-15) in the free troposphere.

Ozone is important as it shields the Earth's surface from UV radiation. Ozone depletion is becoming a global challenge these days. Depletion depends heavily on season, in late winter and spring [34]; the depletion of the ozone layer is more pronounced due to periods of increased UV-B [2], [31]. The depletion of the ozone layer between the years 1979 to 1991 has a mean value of 46% per decade in the Northern Hemisphere [10]. In several parts of the Northern Hemisphere, researches have shown that the concentration of ozone has increased significantly in the free troposphere and at the surface [7], [15], [22], [23], [36].

Ozone found in the troposphere plays an essential role in establishing the oxidising capacity of the atmosphere, both in its elementary form as well as a precursor of the hydroxyl radical OH [4], [29]. Some fifteen years ago, it was observed that the global increase in ozone concentration was not the only problem, but it also dealt with photochemical production. Subsequently, concern about tropospheric ozone amplified [13], [38].

The augmentation in tropospheric ozone concentration is due to higher emissions of its precursors, which are the products of human activities. However, the concentration is lessened in areas where there is heavy vehicular traffic as ozone reacts with NO_x to produce nitrogen dioxide and oxygen [2], [1], [5], [35].

This study has been conducted at three different air monitoring stations in the Malaysia, namely Putrajaya, Petaling Jaya and Jerantut which are located at three different regions. This study also aims to describe the variations of ozone in weekday and weekends as well as the daily maximum recorded at selected monitoring stations. Moreover, comparisons of average and maximum concentrations of ozone and the other are based on backward trajectories considered using the HYSPLIT Model for the three stations.

Negar Banan, MSc in Environmental Assessment and Monitoring at School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia. (Mobile phone: 006-0173239860; e-mail: artibanan@yahoo.com).

Mohd Talib Latif, Associate Professor at School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia. (Mobile phone:006-0193032416; fax: 006-03 89213357; e-mail: talib@ukm.my)

II. Methodology

A. Location of Sampling Stations

The stations used in this study were considered at urban and rural areas in Malaysia. The Putrajaya air monitoring station (N02º 55.915', E101º40.909'; S1) is a recently built township in the Selangor state of Malaysia. It was declared a federal territory on the 1st February 2001 and hosts the administrative offices, as well as the Federal Government of the country. It is located 24 km south of Kuala Lumpur and 20 km from the Kuala Lumpur International Airport and covers an overall area of 49.30 kilometers square. The Petaling Jaya air monitoring station (N03º06.140', E101º43.330'; S2) is located in the Selangor state of Peninsular Malaysia, more precisely within the Klang Valley region and covers an area of 97.2 kilometers square. This sampling station is the nearest station to Kuala Lumpur's city centre and is surrounded by industries, residential and commercial areas and the area is very compacted.

The last air quality monitoring station is in Jerantut, Pahang (N03º 55.59', E102º 22.120'; S3). It is located 200 kilometres from Kuala Lumpur, and 180 km from Kuantan. This monitoring station is located at the Malaysian Meterological Deparment at Batu Embun, Jerantut, Pahang in the middle of the Malaysia (Fig. 1). In fact, Natural forest, soil dust, open burning and a low number of motor vehicles are expected to contribute to air quality status at this monitoring station.

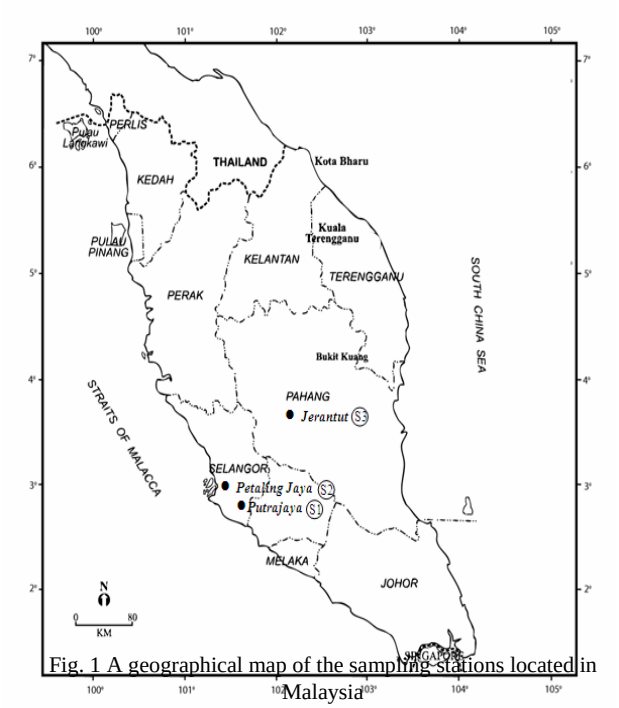


Fig. 1 A geographical map of the sampling stations located in Malaysia

B. Air Quality Data

The air quality data were collected from the air quality monitoring sites by the Department of the Environment (DOE) in Malaysia is managed by a private company, Alam Sekitar Sdn Bhd (ASMA). The overall air quality data used in this study was collected from January to December (2005-2009).

C. Trajectory Analysis

The backward trajectories of atmospheric pollutants have been determined by using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model introduced by the National Oceanographic and Atmospheric Administration through the website: http://www.arl.noaa.gov/ready.html at different monsoon seasons in Malaysia. The model assumed that there was a well-mixed layer in which transports the pollutants and, then dispersion takes place. HYSPLIT Model, shows that the trajectories to these two main stations, namely Petaling Jaya and Putrajaya, have been developed for 72 hour on the 5th of February 2009 (North East Monsoon), the 1st of April 2009 (North East monsoon), the 13rd of April 2009 (North East Monsoon), the 7th of Jun 2009 (South West Monsoon), the 12th of Jun 2009 (Inter-monsoon) and the 3rd of December 2009 (North East Monsoon).

III. Results

Comparisons of the Weekly Concentrations of Ozone for the Three Study Areas

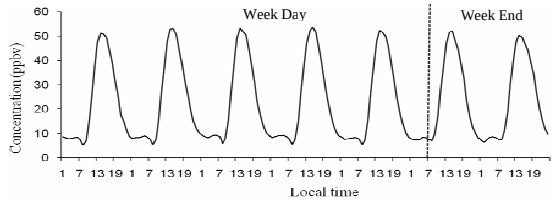
The higher ozone level was found during the weekends (Saturday and Sunday) than in weekdays (from Monday to Friday); in addition to that it has been widely monitored at urban sites all over the world [11], [26], [29], [33]. Conversely, Beaney and Gough [3], Pudasainee et al. [27] emphasized that this phenomenon was not monitored or not found at some remote rural sites.

In 2005 and 2009 the ozone concentrations of weekdays and weekend presented a clear contrary characteristic of an anti-weekend effect with higher ozone level in weekdays than in weekend. Fig.2 indicated the results of the concentration of O_3 in accordance to the weekly pattern. The result of the concentration of O_3 in accordance to the weekly pattern shows that there was little differences between the concentrations of O_3 in working days (Monday to Friday) and in non-working days (Saturday and Sunday). The result of ANOVA test shows that there is a statistically significant difference in the amount of ozone during weekdays and weekends in Jarantut and Petaling Jaya. However, there exists no statistically significant difference in the amount of ozone in Putrajaya during weekdays and weekends.

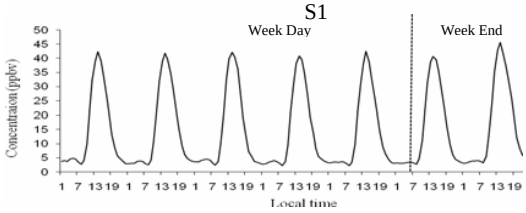
Additionally, the main causes of emissions of all sorts of airborne pollutants are by human activities. In this regard these emissions affects the weekly cycle of ambient pollutant concentrations. In the past decade, ozone has been the subject of research interest of the weekly and weekend differences in ambient concentrations of air pollutants. In the light of that studies conducted by Lal et al. [15], Lee et al. [26], Qin et al. [28] reveal that high concentrations of O_3 on weekends due to differences in the rate of NO_2 and VOC contamination which results into a reduction in the ratio between VOC and NO_2 and occur during weekend. During weekends, the primary reduction of pollution is caused by the decrease in traffic overcrowding over the weekend, this is because majority of

people spend more in their houses rather than out and this leads to the increase in the formation of O_3 on weekends.

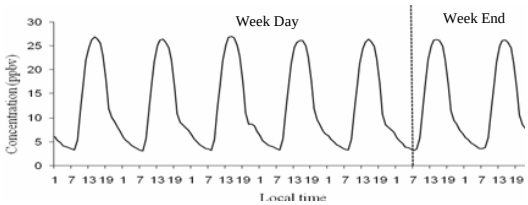
In the light of that, stresses more on this phenomenon that during weekends a decrease in absorption of sunlight resulting in enhanced ozone formation is due to lower fine particle concentration [18], [19]. Similarly, Han et al. [9] elaborate on this point by stating that the impact of the weekend can be demonstrated to some extent using the following mechanism: low NO emissions during weekend mornings consume less O_3 whereas in the daytime it cannot be depleted further which lead to accumulation of ozone. In the next section, the researcher will discuss the monthly concentrations of ozone for the three studied areas.



S1



S2

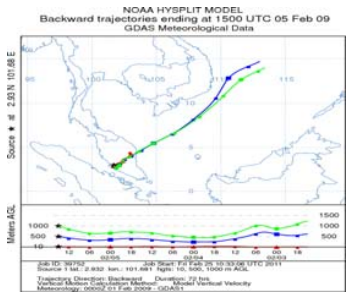


S3

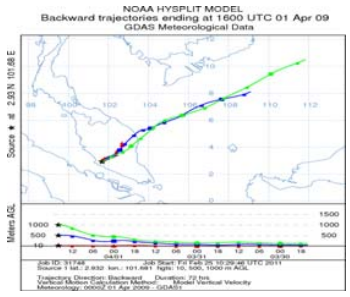
Fig. 2 Concentration (ppbv) versus local time according to the weekdays/ weekend at three monitoring stations

Comparisons of the Trajectory Concentrations of Ozone for the Three Study Areas

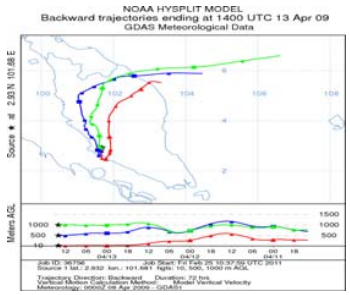
Back trajectory analysis using the HYSPLIT Model, Fig.3 shows that the wind movements came from 10 meters from the surface sea at all three monitoring stations within 72 hour. The wind system is large during the inter-monsoon season in June. The north-east monsoon is usually connected to the wet season in West Peninsular which occurs annually between November and March. As a result, it does not contribute to the amount of anthropogenic sources, particularly from biomass burning, coming from the east part of the Malaysian Peninsular. The O_3 concentration increases in the dry season and was influenced by factors such as high temperatures and UV radiation, which is at the maximum strain and pressure [6], [8], [14], [16], [19], [20], [21], [31], [39].



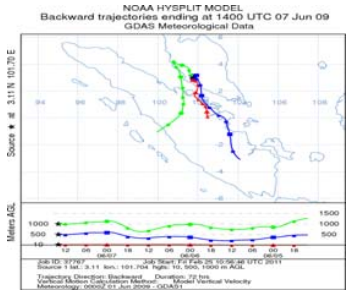
S1



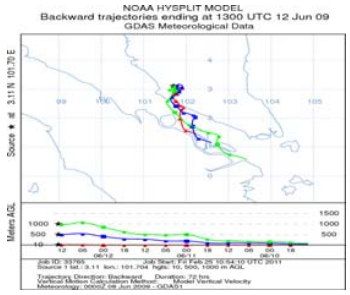
S1



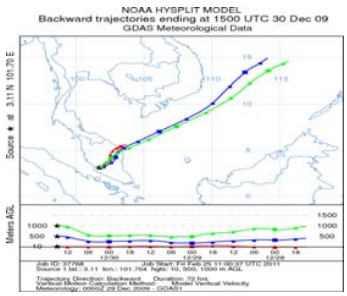
S1



S2



S2

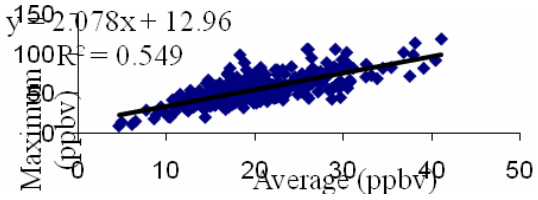


S2

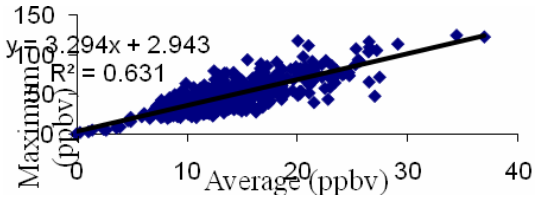
Fig. 3 Backward trajectory of wind direction for the three monitoring stations in 2009

Comparisons between Average and Daily Maximum

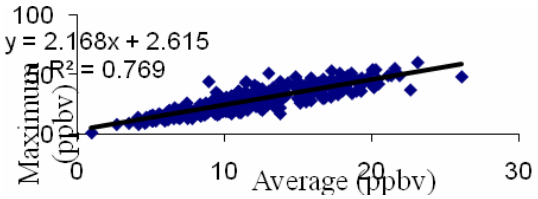
The correlation relationship between maximum value daily and average value daily in the three stations indicated that the maximum daily value has a significant positive correlation with the average daily value. When there was an increase in the points of the maximum daily, the average daily increased as well due to the positive slop that was shown in the below scree plot. Therefore, as can be observed, the correlation coefficients and slops are positive. Correlation value showed positive X and Y equation of the line. Fig4. indicated that the value for Putrajaya (S1) was at R^2= 0.549), Petaling Jaya (S2) was at R^2= 0.631) and Jerantut (S3) was at R^2= 0.769). In terms of the concentration of air pollutants, it was shown that the level of ozone in three stations tend to increase. This increase was also recorded in the atmosphere in all three stations from 2005 to 2009. It was obvious that the urban ozone concentrations had a trend upward. With regards to the comparisons of average and maximum concentrations of ozone for the three stations, it was reveal that the strongest significant correlation was recorded in Jerantut station with the value R^2= 0.769. Thus this correlation pattern indicated that there were the same sources of atmospheric pollutants recorded in Jerantut. Similarly, the second highest significant correlation was recorded in Petaling Jaya with (R^2= 0.631). Inasmuch as Petaling Jaya was located in urban and industrial area, this would lead to the existence of atmospheric pollutants from various sources, it will be more influenced by the movement of motor vehicles.



S1



S2



S3

Fig. 4 Average and daily maximum variations of ozone concentration at selected monitoring stations

IV. Conclusion

The results from this study show that the averaged concentration of all atmospheric pollutants recorded at Putrajaya, Petaling Jaya and Jerantut are under the permissible value recommended by the Malaysian Department of Environment. However, urban areas had the higher level of O_3 concentration than when compared with the rural area (Jerantut) used in the study. The findings showed that meteorological factors such as sunlight and the ambient temperature are expected to be associated with the concentration of ozone. As indicated by the HYSPLIT Model (the northeast monsoon), the temperature and wind direction can also influence the concentration of ozone in the atmosphere of the area being studied.

It is hoped that these findings help the associated authority bodies in Malaysia to begin to plan strategies and formulate an effective plan to reduce the emissions from motor vehicles and other anthropogenic sources. It is also hoped that these findings will be useful to the improvement in the knowledge of photochemical air pollution in the Asian region, especially Malaysia.

References

[1] Y.N. Ahammed, R.R. Reddy, K.R. Gopal, K. Narasimhulu, D.B. Basha, L.S.S. Reddy, and T.V.R. Rao, "Seasonal variation of the surface ozone and its precursor gases during 2001-2003 measured at Anantapur (14.628N), a semi-arid site in India," *Atmospheric Research*, Vol. 80 pp.151-164, 2006.

[2] R. Atkinson,"Atmospheric chemistry of VOCs and NO_x," *Atmospheric Environment*, Vol. 34, pp. 2063-2101, 2000.

[3] G. Beaney, and W.A. Gough, "The influence of tropospheric ozone on the air temperature of the city of Toronto, Ontario, Canada," *Atmospheric Environment*, Vol. 36, pp. 2319-2325, 2002.

[4] G. Chand, and S. Lal, "High ozone at rural site in India," *Atmos. Chem. Phys*, Vol. 4, pp. 3359-3380, 2004.

[5] J. Chen, W. Wang, J. Zhang, H. Liu, L. Ren, X. Liu, W. Zhang, and X. Wang,"Characteristics of gaseous pollutants near a main traffic line in Beijing and its influencing factors," *Atmospheric Research*, Vol. 94, pp. 470-480, 2009.

[6] S.B Debaje, and A.D. Kakade, "Surface ozone variability over western Maharashtra, India," *Hazardous Materials*, Vol.161, pp. 686-700, 2009.
[7] S.B. Debaje, and A.D. Kakade, "Weekend effect over rural and urban site in India," *Aerosol Air Qual*, Vol. 6, pp. 322-333, 2006.
[8] J. Fenger, "Urban air quality," *Atmospheric Environment*, Vol. 33, pp. 4877-4900, 1999.
[9] S. Han, H. Bian, Y. Feng, A. Liu, X. Li, F. Zeng, and X. Zhang, "Analysis of the Relationship between O_3, NO and NO_2 in Tianjin, China, "*Aerosol and Air Quality Research*, Vol. 11, pp. 128-139, 2011.
[10] Hollandsworth, S.M., McPeters, R.D., Flynn, L.E., Planet, W., Miller, A.J., & Chandra, S. "Ozone trends deduced from combined Nimbus 7 SBUV and NOAA 11 SBUV/2 data," *Geophys. Res*, Vol. 8, pp. 905-908, 1995.
[11] M.E. Jenkin, T.J. Davies, and J.R. Stedman, "The origin and day-of-week dependence of photochemical ozone episodes in the UK," *Atmos Environ*, Vol. 36, pp. 999-1012, 2002.
[12] K. Jokela, K. Leszczynski, R. Visuir, and L. Ylianttlia, "Increased UV exposure in Finland," *Photochem. Photobiol*, Vol. 62, pp. 101-107, 1995.
[13] P.D. Kalbokas, and C.C. Repapis, "A climatological study of rural surface ozone in central Greece," *Atmos. Chem. Phys*, Vol. 4, pp. 1139-1147, 2004.
[14] M. I. Khoder, "Diurnal, seasonal and weekdays-weekends variations of ground level ozone concentrations in an urban area in greater Cairo," *Environmental Monitoring and Assessment*, Vol.149, pp. 349-362, 2009.
[15] S. Lal, M. Naja, and B.H. Subbaraya, "Seasonal variations in surface ozone and its precursors over an urban site in India," *Atmos. Environ*, Vol. 34, pp. 2713-2724, 2000.
[16] Y.C. Lee, M. Wenig, and X. Yang, "The emergence of urban ozone episodes in autum and air temperature rise in Hong Kong," *Air Quality. Atmosphere Health*, Vol. 2, pp. 111-121, 2009.
[17] L.C. Marr, and R.A. Harley, "Modeling the Effect of Weekday Weekend Differences in Motor Vehicle Emissions on Photochemical Pollution in Central California," *Environ. Sci. Technol*, Vol. 36, pp. 4099-4106, 2002a.
[18] L.C. Marr, and R.A. Harley, "Spectral Analysis of Weekday Weekend Differences in Ambient Ozone, Nitrogen Oxide and Non-methane Hydrocarbon Time Series in California," *Atmos. Environ*, Vol. 36, pp. 2327-2335, 2002b.
[19] H. Mayer, "Air pollution in cities," *Atmospheric environment*, Vol. 33, pp. 4029-4037, 1999.
[20] M.F. Md Isa, 2006. Kualiti udara di Johor Bahru. Skudai: Universiti Teknologi Malaysia.
[21] T. Moreno, J. Lavín, X. Querol, A. Alastuey, M. Viana, and W. Gibbons, "Controls on hourly variations in urban background air pollutant concentrations," *Atmospheric environment*, Vol. 43, pp. 4178-4186, 2009.
[22] P.R. Nair, D. Chand, S. Lal, M. Naja, K. Parameswaran, S. Ravindran, and S. Venkataramani, "Temporal variations in surface ozone at Thumba (8.6°N, 77°E) - a tropical coastal site in India," *Atmos. Environ*, Vol. 36, pp. 603-610, 2002.
[23] M. Naja, and S. Lal, "Surface ozone and precursor gases at Gadanki (13.5°N, 79.2°E), a tropical rural site in India," *Geophys. Res*, Vol. 107, pp. 13, 2002.
[24] E. Paoletti, "Impact of ozone on Mediterranean forests: a review," *Environmental Pollution*, Vol.144, pp. 463-474, 2006.
[25] V. Pont, and J. Fontan, "Comparison between weekend and weekday ozone concentration in large cities in France," *Atmos. Environ*, Vol. 35, pp. 1527-1535, 2001.
[26] PORG. 1993. "Ozone in the United Kingdom. Third Report of the UK Photochemical Oxidants Review Group, Department of the Environment, London. Published by Institute of Terrestrial Ecology, Bush Estate, Penicuik, Midlothian, EH260QB, UK. ISBN: 0705816834, www.aeat.co.uk/netcen/airqual/reports/home.html.
[27] D. Pudasainee, B. Sapkota, A. Bhatnagar, S.H. Kim, and Y.C. Seo, "Influence of weekdays, weekends and bandhas on surface ozone in Kathmandu valley," *Atmospheric Research*, Vol. 95, pp. 150-156, 2009.
[28] Y. Qin, G.S. Tonnesen, and Z. Wang, "Weekend/weekday differences of ozone, NO_x, CO, VOCs, PM_{10} and the light scatter during ozone season in southern California," *Atmos. Environ*, Vol. 38, pp. 3069-3087, 2004.
[29] R.R. Reddy, K.R. Gopal, L.S. Reddy, K. Narasimhulu, K.R. Kumar, Y.N. Ahammed, and C.V.K. Reddy, "Measurements of surface ozone at semi-arid site Anantapur (14.62°N, 77.65°E, 331 masl) in India, " *Atmospheric Chemistry*, Vol. 59, pp. 47-59, 2008.
[30] G. Seckmeyer, B. Mayer, R. Erb, and G. Bernhard, "UV-B in Germany higher in 1993 than in 1992," *Geophysical Research Letters*, Vol. 21, pp. 577-580, 1994.
[31] W. Shan, Y. Yin, H. Lu, and S, Liang, "A meteorological analysis of ozone episodes using HYSPLIT model and surface data," *Atmospheric Research*, Vol. 93, pp. 767-776, 2009.
[32] W.P. Shan, Y.Q. Yin, J.D. Zhang, and Y.P. Ding, "Observational study of surface ozone at an urban site in East China," *Atmospheric Research*, Vol. 89, pp. 252-261, 2008.
[33] A. Sorg, 1996. Stratospheric Ozone, 1996. United Kingdom Stratospheric Ozone Review Group, Depatmant of the Environment Sixth Report, HMSO, London.
[34] M. Trainer, D. Parrish, P. Goldan, J. Roberts, and F. Fehsenfeld, "Review of observation-based analysis of the regional factors influencing ozone concentrations," *Atmos Environ*, Vol. 34, pp. 2045-2061, 2000.
[35] J. Tu, Z.G. Xia, H.S.Wang, and W.Q. Li, "Temporal variations in surface ozone and its precursors and meteorological effects at an urban site in China," *Atmospheric Research*, Vol. 85, pp. 310-37, 2007.
[36] C. Varotsos, K. Kondratyev, and M. Efstathiou, "On the seasonal variation of the surface ozone in Athens, Greece," *Atmos. Environ*, Vol. 35, pp. 315-320, 2001.
[37] Vingarzan, R. "A review of surface ozone background levels and trends," *Atmospheric Environment*, Vol. 38, pp. 3431-42, 2004.
[38] A. Volz, and D. Kley, "Evolution of the Montsouris series of ozone measurements made in the nineteenth century," *Nature*, Vol. 332, pp. 240-242, 1988.
[39] j. Zheng, L. Zhong, T. Wang, P K. K. Louie, and Z. Li, "Ground level ozone in the Pearl River delta region: Analysis of data from a recently establish regional air quality monitoring network," *Athmospheric environment*, Vol. 44, pp. 814-823, 2009.