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REVIEW OF SURFACE OZONE AND ITS PRECURSORS IN URBAN ATMOSPHERE OF ISTANBUL, TURKEY FOR 2002-2003

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ABSTRACT

Surface ozone, the most well known substance within photochemical smog, plays an important role in affecting the regional climate and causing harmful effects on health and ecosystem. Surface ozone in urban areas is generated by a series of complicated photochemical reactions involving NO_x and HCs in the presence of sunlight. Surface ozone concentrations are increasing in the city depending on increasing number of cars that use mostly gasoline and poor dispersion conditions. Istanbul is one of the highly populated cities in the world and the most populated city in Turkey, with a population of about 12 million inhabitants. The history of photochemical air pollution in Istanbul is not long. The number of motor vehicles in Istanbul increased at a very fast rate (according to the figure of 2003 its about 1.7 million). It is two fold in the last ten years. High ozone days in ozone seasons are frequently observed when anticyclonic pressure systems are in the vicinity of Istanbul area.

In this study, the interaction patterns of nitric oxides and ozone are investigated based on measured data based in two urban sites in Istanbul, during the period of 1998-2003. The paper presents also an investigation of meteorological features that were present during high ozone days in Istanbul in the same period. The study identifies both synoptic and mesoscale controlling patterns as well as vorticity fields over the region and examines the relationships between surface ozone concentrations and meteorological parameters. In order to understand the characteristics of ozone formation in this region, meteorological parameters are examined according to classification of ozone levels and its precursors with high ozone and nonhigh ozone days. Furthermore the interactive characteristics between O_3 and NO_x are statistically studied.

Key Words: surface ozone, photochemical pollution, episode

1. INTRODUCTION

Surface ozone in urban areas is generated by a series of complicated photochemical reactions involving NO_x and HCs in the present o sunlight. Ozone the most well known substance within photochemical smog plays an important role in affecting the regional climate and causing harmful effects on health and ecosystem. Many studies of surface ozone problems in the lower surface atmosphere have been engaged in several countries (Hanna and Chang, 1995; Chang et al., 1998; Xu et al., 1998; Ghim et al., 2001). Photochemical smog problem is increasing in importance with the number of vehicles in the urban areas. Ozone episodes are rare in some of the cities which vehicle numbers are rather less than the developed countries. In China, ozone episodes are rare because vehicle numbers are much less than those United States and other western countries (Xu et. al., 1998). As an example, Shanghai has a population of 10 million, but its vehicle number approximately of 300,000. Therefore, Chinese government has not paid a great deal of attention to the problem (Xu et. al., 1998). Furthermore, photochemical air pollution is a complex problem involving as it does both atmospheric diffusion processes as well as complex reactions. Photochemical O_3 problems become an especially important issue during the hot summers.

The history of photochemical air pollution in Istanbul is not long. The high O_3 levels now occur most frequently, O_3 pollution was low in 1998 throughout 2000 (Topcu and Incecik, 2002). The city did have serious SO_2 and TSP problems (Incecik, 1996; Unal et. al., 2000; Topcu et al., 2003). However, fuel use switched from high sulfur coal to liquefied natural gas in mid 1990s. In addition, the number of cars increased in Istanbul at a very fast rate, from 600,000 in 1990 to 1.7 million in 2003. As a consequence, air quality problems in Istanbul shifted from those caused by primary pollutants such as SO_2 and TSP to those caused by secondary pollutants such as O_3. Furthermore, O_3 problems will be not limited in Istanbul, quickly spread to many other cities. Surface ozone concentrations are increasing in the city depending on increasing number of cars that use mostly gasoline and poor dispersion conditions. Istanbul is one of the highly populated cities in the world and the most populated city in Turkey, with a population of about 12 million inhabitants. The number of motor vehicles in Istanbul increased at a very fast rate (according to 2003 Figureure it's about 1.7 million). It is two fold in the last ten years.

High ozone days in ozone seasons are frequently observed when anticyclonic pressure systems are in the vicinity of Istanbul area. Furthermore, photochemical O_3 problems become an especially important issue during the hot summers (Chang et al., 1998; Xu et al., 1998; Ghim et al., 2001)

In this study, the interaction patterns of nitric oxides and ozone are investigated based on measured data based in two urban sites in Istanbul, during the period of 2002-2003.

The paper presents also an investigation of meteorological features that were present during high ozone days in Istanbul. The study identifies the region and examines the relationships between surface ozone concentrations and meteorological parameters. In order to understand the characteristics of ozone formation in this region, meteorological parameters are examined according to classification of ozone levels and its precursors with high ozone and nonhigh ozone days. Furthermore the interactive characteristics between O_3 and NO_x are statistically studied.

2. INSTRUMENTATION AND MEASUREMENTS

Surface ozone concentrations have been measured in Istanbul in two sites, Kadikoy and Sarachane (Aksaray) in both Asian and European side of the city. An O_3 41 M ozone by Environment S.A. analyzer based on the absorption of UV radiation is used. The NO_x analyzer, AC31M of Environment S.A is used. The system is based on the chemiluminescence's effect produced by the oxidation of NO by O_3. NO_2 is measured by converting it into NO using the thermal conversion method (GIM, 2000).

One of the best understandings of the indicators of ozone is its peak levels. The peak concentrations are considered in preparing of the air quality standards with their impacts on the health and ecosystem. Figures 1 and 2 give the time series of the daily maximum peak concentrations in 2002 and 2003. Kadikoy site indicates higher concentrations than those at Sarachane. This is due to the characteristics of the Kadikoy measurement station. This station is the center of the traffic in the area. However, Sarachane station expose to the ventilated area.

3. OZONE SEASON PROCESS AND EPISODES IN THE SUMMERS OF 2002-2003

Table 1 indicates the episodic characteristics in the city in 2003 two days before the episode, one day before the episode, episode day, and one day after episode and two days after episodes. Furthermore, ozone precursors were given for daylight hours with their peak levels for both sites in the city. In order to understand the ozone season process, ozone concentrations were classified according to 100 $\mu g/m^3$ as low and high ozone days. Table 2 shows the number of ozone days higher than 100 $\mu g/m^3$ in both sites for the summer months. Furthermore meteorological variables in episode period in 2003 is given in Table 3. June has much higher ozone days than the other months. This may be explained by the more intense solar radiation in June than the July and August (Figure 3).

Diurnal Variation

Photochemical ozone production takes place by photoxidation of CH_4, CO and NMHCs in the presence of sufficient amount of NO_x. In case of rich NO_x air, the production of NO_2 takes place by the reaction of NO and HO_2 or RO_2 which support the ozone production. However, in case of NO_x poor air, as like as rural atmosphere, these peroxy radicals react with ozone and lead to ozone loss (Lal et al,2000).

Average diurnal variations of ozone for June of the ozone seasons in 2002-2003 are shown in Figure 4. During the day, ozone concentration starts increasing gradually after sunrise, attains maximum value during noontime and then decreases. The daytime increase in ozone, which is a pronounced feature of an urban polluted site, is basically due to the photoxidation of the precursor gases such as CO, CH_4, and NMHCs.

In the diurnal cycle of ozone, the nighttime values are low, the minimum ozone concentrations are observed during early morning hours, near the sunrise. Low levels of ozone during early morning hours are due to the combined effects of chemical loss by NO and NO_2 species and suppressed of boundary layer mixing processes.

Diurnal variations in NO_x and NMHCs are shown in Figures 5 and 6 for the summer months in 2002-2003.

The average diurnal variations of NO_x, O_3 and NMHCs show buildup during morning and the late evening hours. The peak values of NMHCs indicate clearly traffic hours in both morning and evening in the city. It can be seen that the NO_x curve matches very well with the O_3 concentrations.

Ozone-NO_X Relationships

It is known that the number of ozone molecules that are produced for every NO_x that is oxidized. This process leads to negative correlation for the relationship between NO_x and ozone. Figures 7 and 8 show the O_3-NO_x relationships for 2002 and 2003 in the summer months.

Ozone and Wind Direction

In order to evaluate a relation between high and low ozone levels and wind direction, the frequency of occurrence of each wind sector and corresponding ozone mean were calculated for the summer months. Figure 9a shows that the wind direction is totally controlled by the orientation NE-ENE and 4% of calm winds for low ozone concentrations. However, dominant wind direction is SW-WSW with a 38.6% calms for high ozone days (Figure 9b).

4. CONCLUSIONS

Photochemical smog problem is increasing in importance with the number of vehicles in urban atmosphere of Istanbul. Furthermore, the variations of ozone in the lower atmosphere are greatly influenced by meteorological factors. In this study, the interaction patterns of nitric oxides and ozone were investigated based on measured data on two urban sites and meteorological factors in Istanbul, during the period of 2002-2003. The high ozone episodes characterized by southwest and west-southwest winds and calm conditions. There is a strong negative correlation between NO_x and ozone. The average diurnal variations of NO_x, O_3 and NMHCs support the process of the buildup during morning and the late evening hours. The peak values of NMHCs come from city traffic in both morning and evening in the city.

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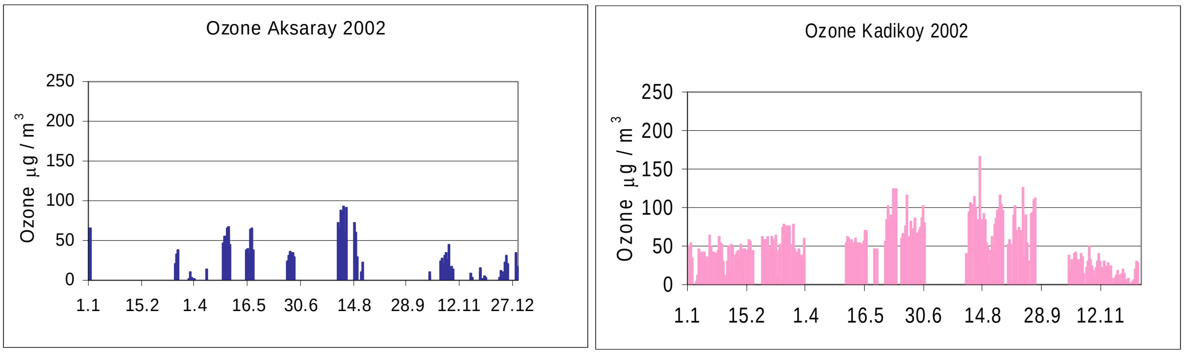

Figure 1. Daily maximum ozone concentrations in 2002 at Aksaray and Kadikoy.

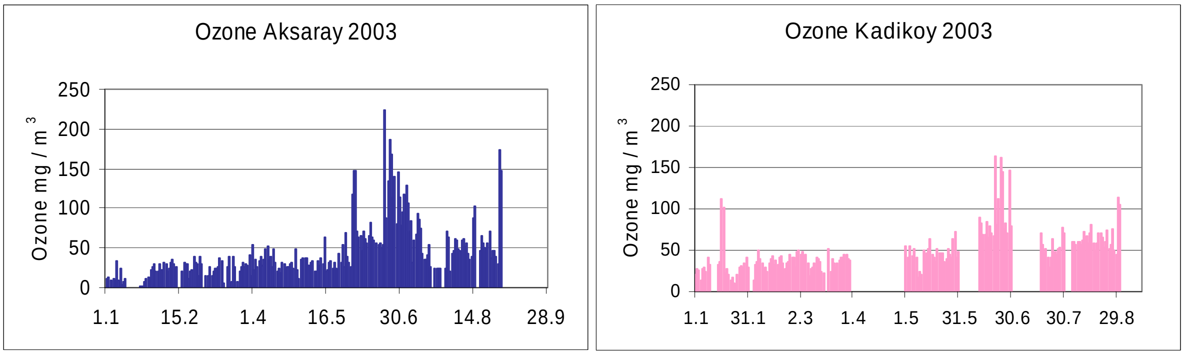

Figure 2. Daily maximum ozone concentrations in 2003 at Aksaray and Kadikoy.

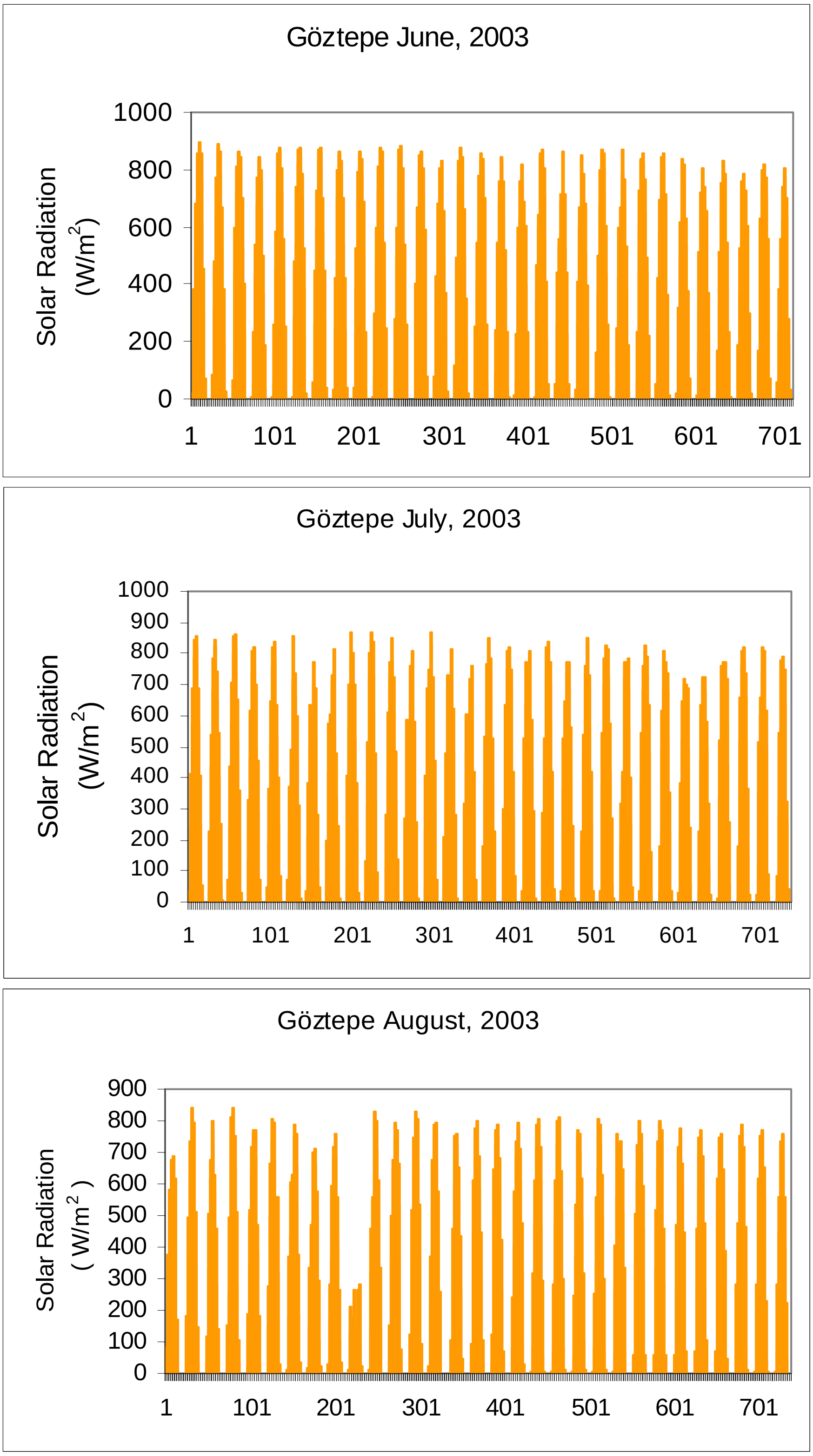

Figure 3. Solar radiation in the summer months of 2003

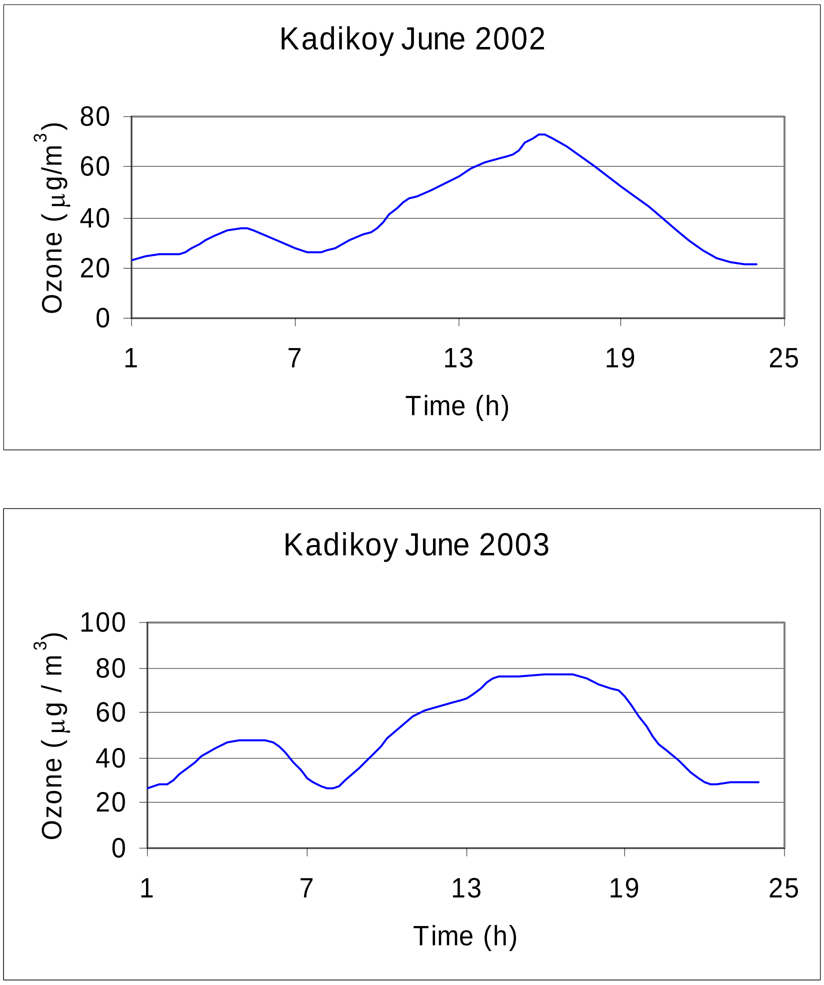

Figure 4. Diurnal Variation of ozone in June of 2002-2003

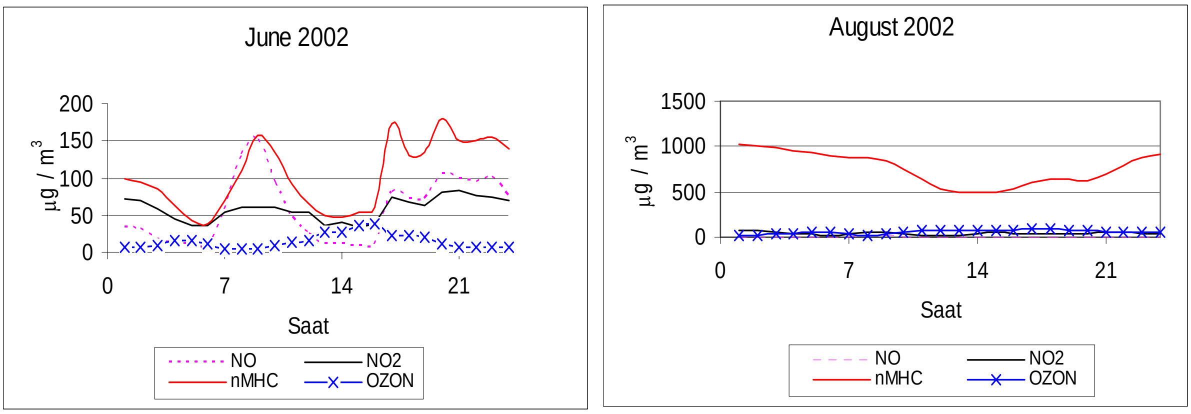

Figure 5. Diurnal variations of NO_x and NMHCs in 2002 summer months at Kadikoy (July 2002 data is not available)

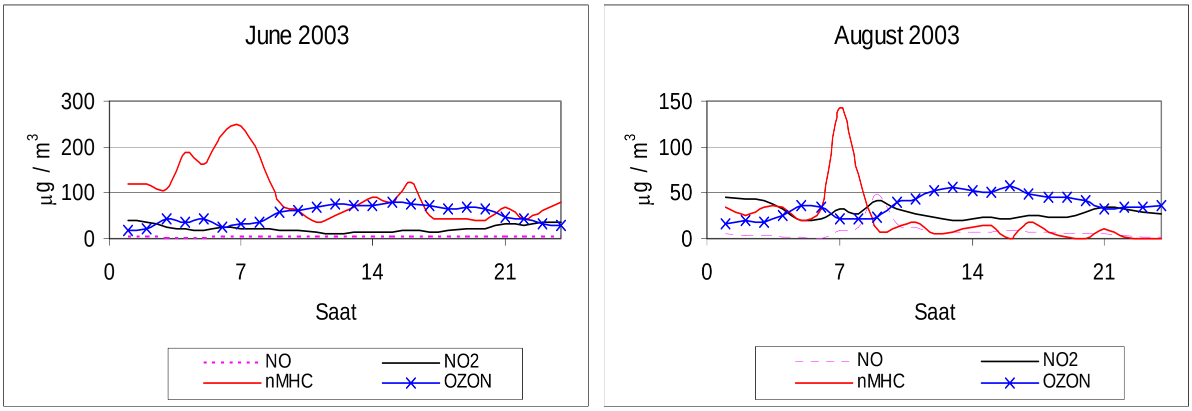

Figure 6. Diurnal variations of NO_x and NMHCs in 2003 summer months at Kadikoy (July 2003 data is not available)

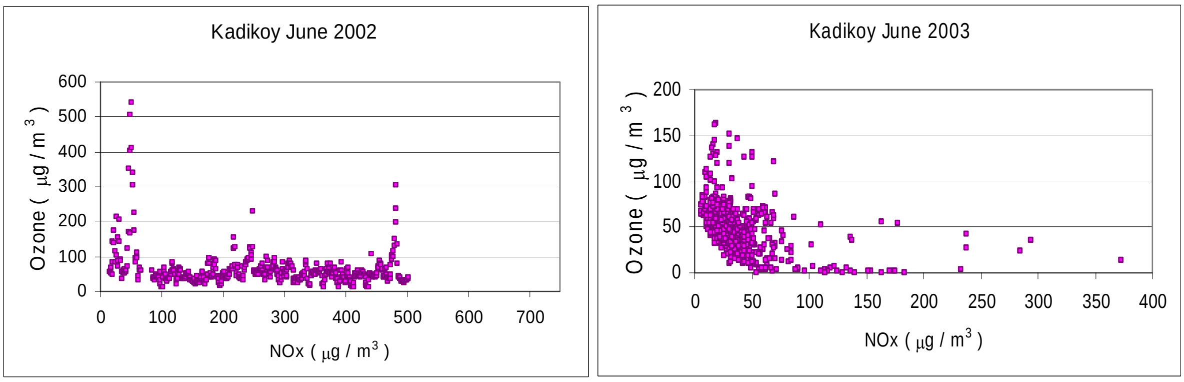

Figure 7. O3-NOx Relationships for June 2002 (r=-0.01) and 2003 (r= - 0.44)

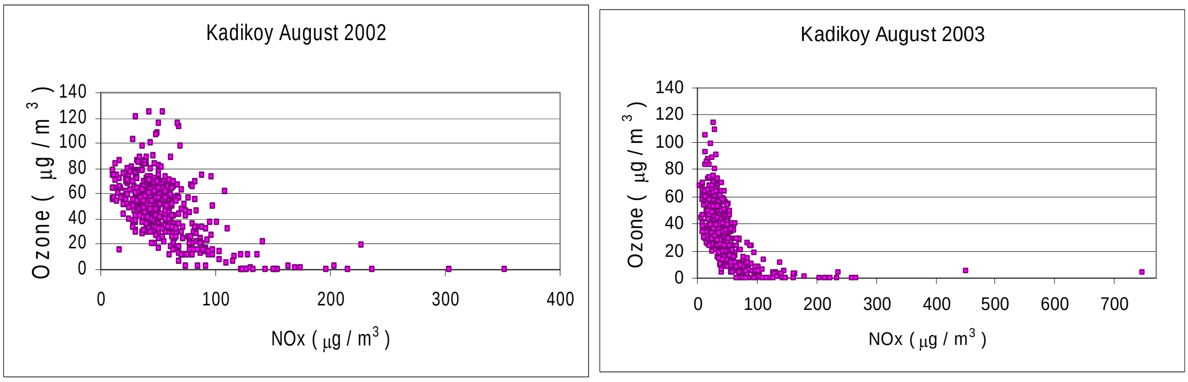

Figure 8. O3-NOx Relationships for August 2002 (r=-0.55) and 2003 (r=-0.46)

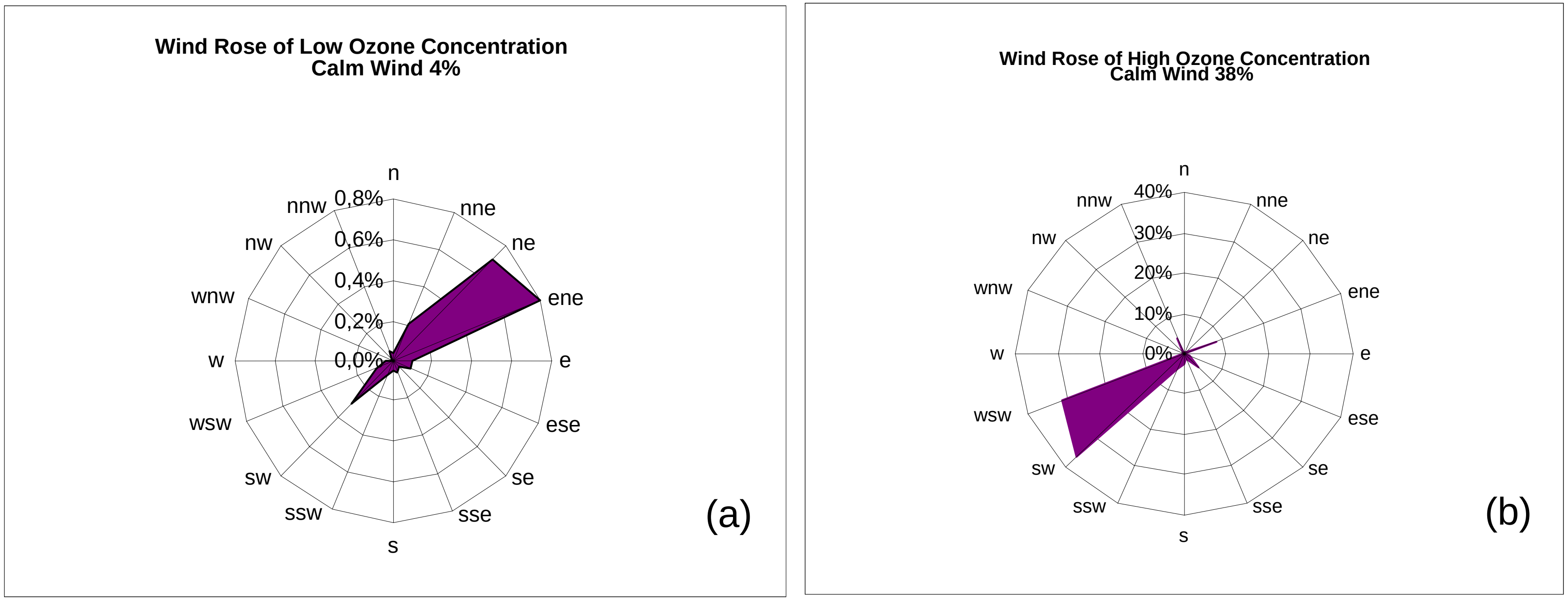

Figure 9. Ozone pollution roses for summer months (June, July and August) in 2003 for (a) O_3 < 100 µg / m^3 and (b) O_3 > 100 µg / m^3