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Characteristics of Ozone Concentration in the Rural Area of Korea

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Abstract

Continuous measurements of ground-level ozone (O_3) were made in five minutes intervals in the rural area of Korea from July 1993 to June 1994. This site is located in Chongwon, near latitude 36.4° N, longitude 127.6° E. The results show that the one-year mean value was 17 ppb, and monthly mean ranged from 6 to 47 ppb. A pronounced maximum in summer and a minimum in winter were found, and these were related to anthropogenic emission and photochemical reaction. Diurnal variations of ozone concentration showed a normal distribution with a maximum at 15:00 - 16:00 and a minimum at 07:00 - 08:00. During the period when ozone concentration was very high (> 80 ppb), the stable winds were from N and NW; on the other hand, when ozone concentration was very low, air movement in the large scale was from the North Pacific Ocean. This suggests that in the rural area the long range transport of anthropogenic pollutants from distant sources can contribute to the larger contribution than the generation of ozone from local sources in the rural area.

Keywords : ground-level ozone, diurnal variation, long-range transport of air pollutants, ozone in Korea.

1. Introduction

Nowadays, the increasing of the concentration of trace gas species in the atmosphere, such as O_3, CO_2, CH_4, NO_x, hydrocarbons etc., and their resulting impact on global climate and local air quality have become one of most important scientific issues. It is recognized that these trace gases are enhancing the greenhouse effect by increasing the infrared opacity of the atmosphere, therefore reducing the escaping capacity of heat from the earth into space so that the long term increases in ozone and other gases are expected to produce important climatic effect, in particular a change in global radiative budget. Moreover, ozone both in the troposphere and stratosphere can plays a major role, limiting the penetration of sunlight between 2000 and 3000Å.

The very nature of life and its evolutionary path has been influenced by ozone, and the importance of photochemical oxidants for the atmosphere and biosphere has been clearly recognized (Chung, 1977 ; McElroy, 1974). Two sources of ozone in the natural troposphere have been suggested; the one is injection from the stratosphere (Chung and Dann, 1985) and the other is photochemical production via NOx and NMOC (non-methane organic compounds) of anthropogenic origin. Reactions in the

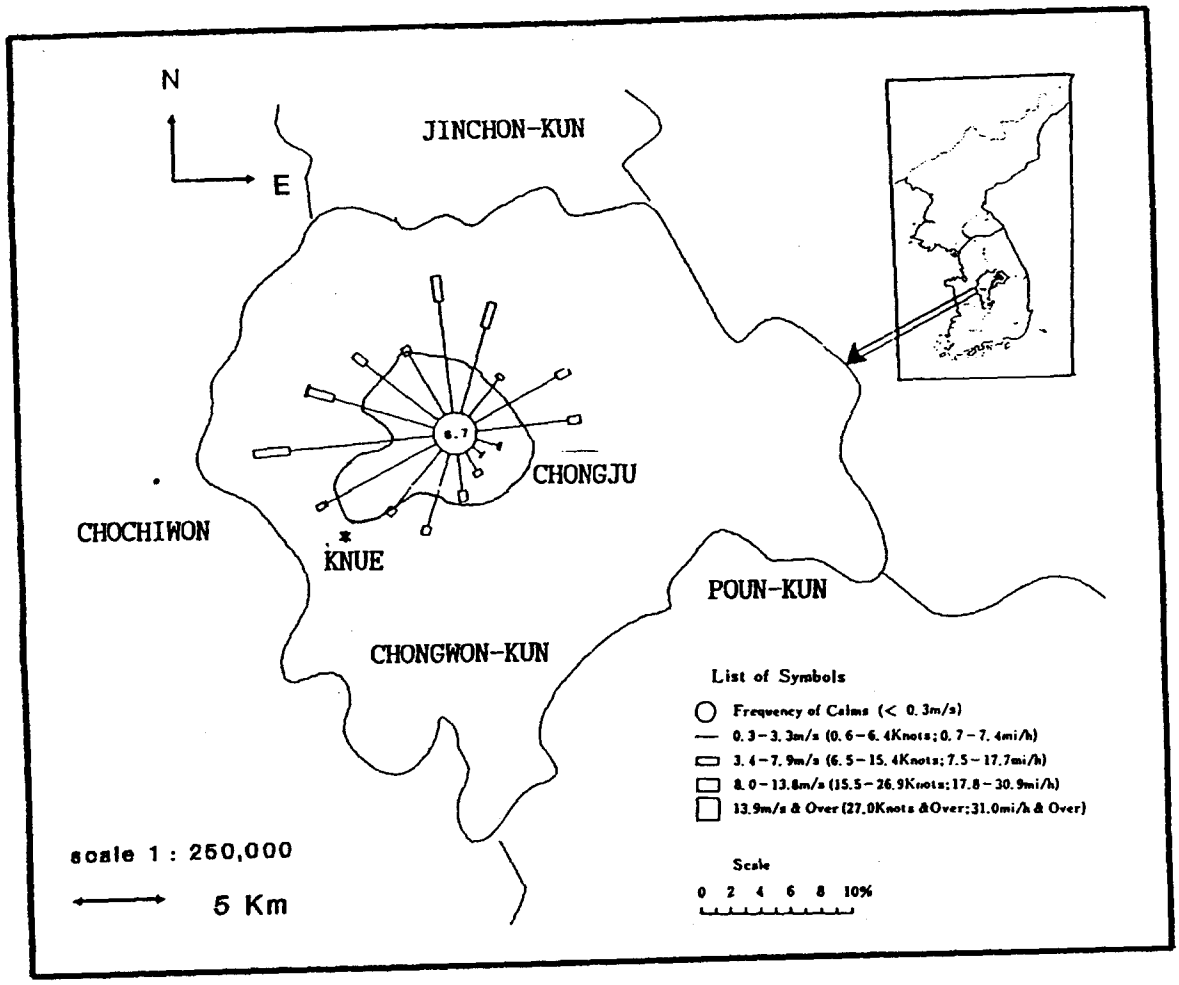

Fig. 1. The location of ozone monitoring site in Chongwon(KNUE). A wind rose indicates frequencies of annual mean wind.

sunlight involving naturally occurring oxides of nitrogen and hydrocarbons or CO are given in the literature (Finlayson-Pitts and Pitts, 1986).

Photochemical air pollution was observed over many urban area and reaction schemes were studied in detail. Researchers also showed that there was a trend of an ozone increase both in Northern and Southern Hemisphere. A long term increase of about 1% per year was detected in two sites, one was in Hohenpeissenberg and the other in Arkona, Germany (Low *et al.*, 1990).

In order to study the long and short term behaviour and trends of atmospheric ozone, the background surface ozone monitorings were made in USA, Canada, Japan, China, Korea etc. (Young and Carmichael 1994), and hourly ozone value at some remote sites had been reported to exceed 80 ppb (Angle and Sandu, 1986; Logan, 1989). At a rural site in central Korea,

the background monitoring of air quality has been carried out since July 1993. The purpose of the present study is to discuss factors playing important roles in the variability of tropospheric ozone observed in Chongwon, Korea.

2. Data

The ozone monitoring was done at Korea National University of Education, which is located about 10 km in the southwest of Chongju city (Fig. 1). the air intake was at the top of Science Building with 12 m high. Westerlies and northwest winds are more common in this area. By using the Chemiluminescent method (Thermo Environmental Instr., Model 49), ozone concentrations had been continuously monitored with the data analysis in intervals of five minutes at the site from July 1993 to June 1994. In order to ensure high quality data, measuring device for ozone was subjected to multi-point calibration on 3-4 weeks basis. In addition, data of non-methane hydrocarbon (NMHC) measurements had been also used to find a possible relationship with ozone.

3. Results and discussion

(1) Annual variation

Statistical summaries of ozone concentrations are shown in Table 1. The annual average of monthly maximum was 37 ppb. Strikingly, the one-year average ozone concentrations at this rural area was 17 ppb in contrast to the observed annual average values in Seoul in 1989 and 1990 which were 11.8 and 10.4 ppb, respectively (Chung and Chung, 1991). The annual variations of ozone concentration in Chongwon are shown in Fig. 2. We found that the monthly average peak value occurred in June 1994, while the minimum value was seen in January 1994. In July 1993 there were many rainy days, and the maritime air was generally producing humid weather occupied in August.

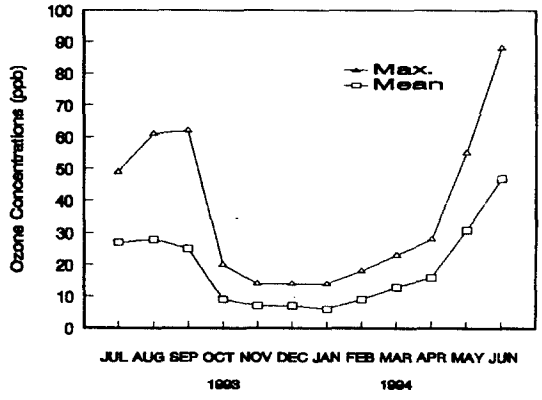

Fig. 2. The monthly variations of ozone concentration.

Table 1. The monthly mean of ozone values from July 1993 to June 1994.

Month	Mean	Max. average	Month	Mean	Max. average
1	6	14	7	27	49
2	9	18	8	28	61
3	13	23	9	25	62
4	16	28	10	9	20
5	31	55	11	7	14
6	47	88	12	7	14

NMHC are emitted mainly by human activity. In general, they play an important role in tropospheric photochemistry. NMHC are believed to react with other primary pollutant NO_x in the sunlight to form a host of

secondary pollutants and ozone is one of very important ones. Scientists have shown that, in general, NO_x are inversely correlated with the high concentrations of ozone and NO_x plays an important role of photochemical precursors in summer (Chung, 1977). Fig. 3 shows the relationship between monthly NMHC and ozone concentrations. Comparing the monthly NMHC and ozone variations, we found the good relationship between NMHC and ozone concentrations. An increase of NMHC from March to June was seen, so the rapid increase of ozone also may due to the excess hydrocarbons released during this period. The NMHC concentration was suspected to be added from the semi-industrial area of Chongwon and by automobile emission in the free way (Seoul to Pusan) which is located in the east direction at about 2 km.

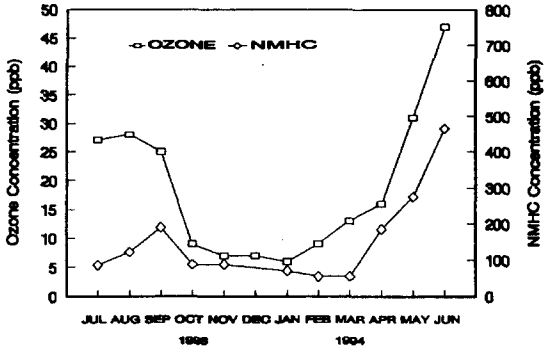

Fig. 3. The monthly mean values of ozone and non-methane hydrocarbons.

(2) Diurnal variations

Ozone is created by photo-dissociation and depleted by the scavenging effect of NO. Ozone generation is increased with increasing temperature (Chung, 1977), and a photochemical generation would be enhanced by the intensity of solar radiation in summer and in afternoon. Diurnal variations for every seasons in this rural area were described very well by a normal distribution in Fig. 4. The pattern of ozone concentrations was unimodal in structure. The peak occurred in 15:00 - 16:00 LST, while in many urban area, maximum values occur at the time of 14:00 - 15:00. This suggests that there was transport of ozone and its precursors from Chongju city or Chochiwon to this rural station. Minimum concentrations of ozone, on the other hand, usually occurred at 07:00 - 08:00. Form comparing four seasonal values, it was evident that the ozone concentrations in summer was higher than that in any other seasons and the concentrations of ozone in winter appear to be the smallest. The hourly ozone concentrations in spring was larger than those in autumn, which as had been suggested that the meteorological conditions during spring time were more favourable for the transport of stratospheric air with high ozone concentrations to the lower troposphere (Kato *et al* 1990; Wundeli and Gehrig, 1990; Young and Carmichael, 1994).

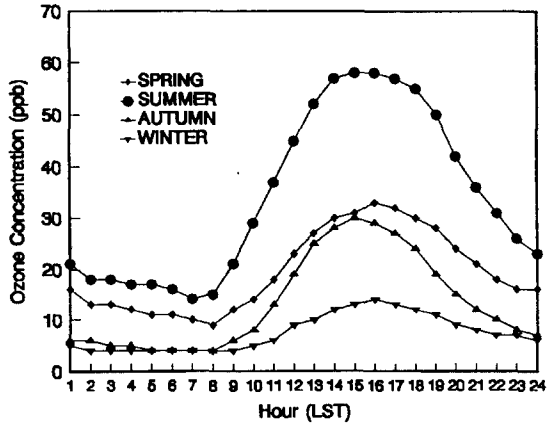

Fig. 4. Diurnal variation of ozone for four seasons.

(3) Meteorological factors

Beside pollution sources, there are many meteorological factors affecting the ozone concentration in the air, such as temperature, precipitation, wind, cloud, etc. (Chung and Chung, 1991). Because of the temperature dependence of photochemical reaction, the high values of ozone were usually found when air temperature and radiation were relatively high. Fig. 5 shows the daily variations of maximum temperature and maximum ozone concentrations for 15 days in June 1994. During this period, whenever the daily maximum temperature increased, the daily maximum ozone concentration also increased; and whenever the maximum temperature decreased, the maximum ozone concentration decreased. It seems that the temperature is the most important factor about the formation of ozone in the air at the ground level. Fig. 6 shows the variations of daily maximum ozone concentrations in August 1993. It can be seen that there was a large variation from 24 to 100 ppb.

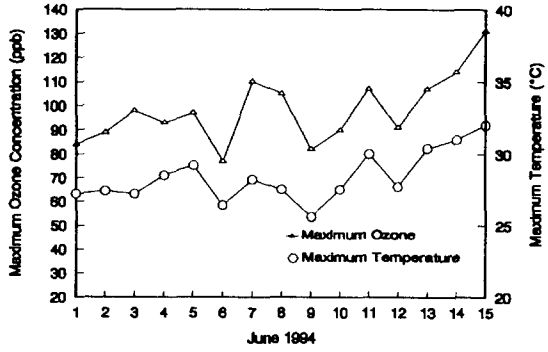

Fig. 5. The relationship between maximum ozone concentration and maximum temperature.

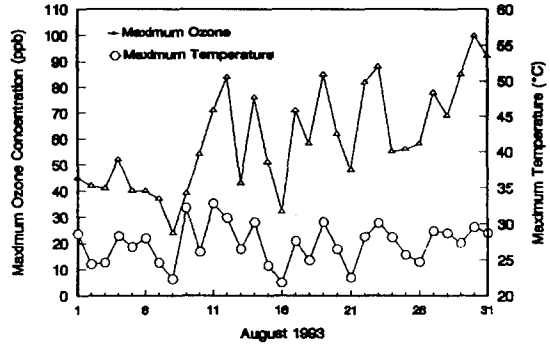

Fig. 6. Daily variations of maximum ozone and temperature in August 1993.

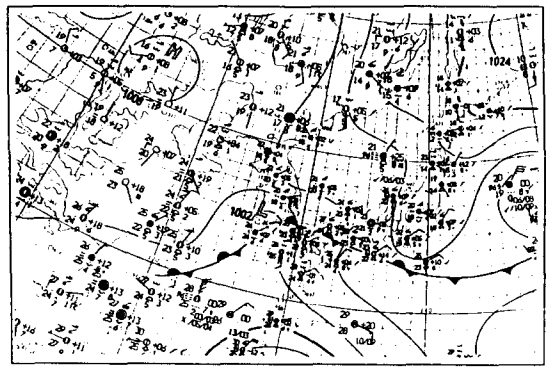

Fig. 7. A surface weather map at 0000 UTC, 8 August 1993.

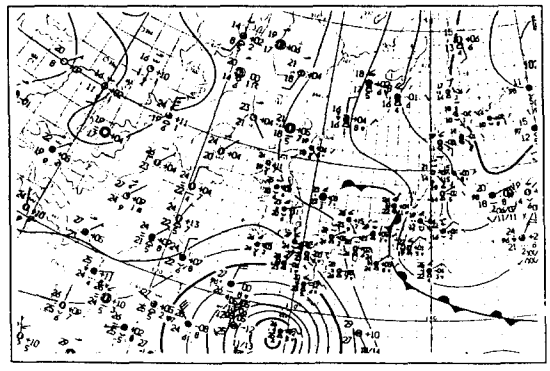

Fig. 8. A surface weather map at 0000 UTC, 9 August 1993.

In this study, August 8 and 9 were selected as typical days with very low ozone

concentration, while 28, 29, 30 and 31 of August with very high ozone concentration days. From Fig. 7, it is shown that a low pressure with a polar (rainy) front was situated over the southern part of Korea. It was generally cloudy with occasional rain showers in the peninsula. In the following day, the cloudy weather still dominated with the maritime air from the NW Pacific Ocean. In particular, with the approach of a typhoon, easterly and south easterly air flows were flowing into central Korea. It was discussed from the trajectory analysis that the relatively clean air produces a very low ozone concentration in contrast to the situation of anthropogenic precursors coming from an industrial area (Chung, 1977). At the rural site of Korea, the low values also observed with a clean air from the ocean and with the condition of cloudy and a low air temperature. We have observed that a typhoon clearly brings in a clean maritime air to the region. As a result, even though the maximum temperature on Aug. 9 was 32.2℃, daily maximum NMHC concentrations for those days were smaller than 120 ppb along with the low ozone values.

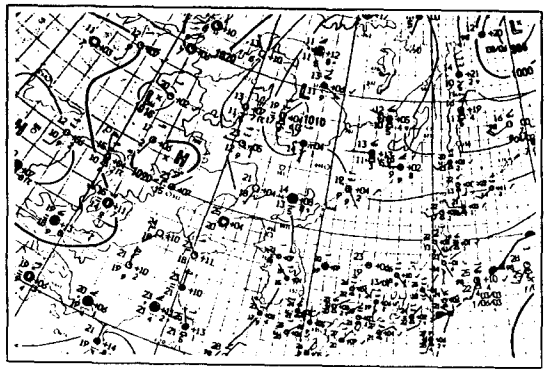

Fig. 9. A surface weather map at 0000 UTC, 30 August 1993.

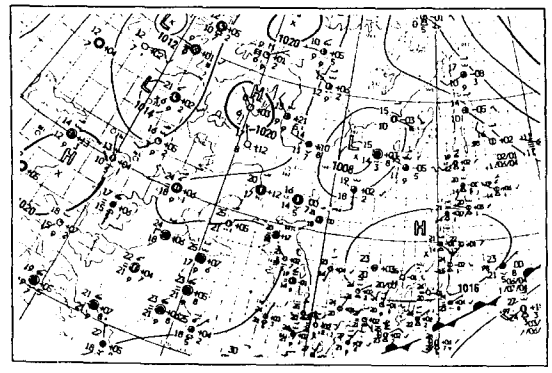

Fig. 10. A surface weather map at 0000 UTC, 31 August 1993.

As can be seen from Fig. 6, the maximum ozone value on Aug. 30 was the highest during this month, while the daily maximum temperature was less than 30℃. Figs. 9 and 10 show the corresponding meteorological charts that the Korean peninsula was under influence of a weak high pressure and of the back side of an anticyclone. In this synoptic situation, a warm and weak continental air flow from the west and northwest was flowing into the central Korea. The recorded daily maximum NMHC concentration exceeded 230 ppb. In addition to the local source at the rural site, regional emission sources in the industrial areas in Korea and China may had been contributed to the high values of observed ozone at the background measurements. As was earlier studies, high values usually observed with the meteorological condition of the (western) backside of an anticyclone and with under the condition of a pressure pattern of "col". At the 1-2 km level altitude, there were general westerlies over Korea and Eastern China. In these synoptic conditions, anthropogenic precursors in the local and regional area can build up and react with other chemical

constituents under the warm air and intense radiation. We observed that the aged precursors from distant sources, e.g. long-range transport of air pollution, usually generate high concentrations of ozone in the biosphere.

4. Conclusion

Ozone concentrations were continuously monitored in a rural site in Chongwon of Korea for a full year. At this regional background station, hourly ozone concentrations exceeding 70 ppb, acceptable air quality level of the WHO, were 38 times. The annual average value of ozone was 17 ppb. The variations of monthly average, for this site being exposed to primary pollutants, showed a pronounced maximum in summer and a minimum in winter. It was observed that in this area the occurrence of ozone had been influenced by local and regional emission of air pollutants. Furthermore, high concentrations of ozone were frequently observed at this station when winds were generally from N and NW, and low concentrations occurred when strong movement of air flow came from the North West Pacific Ocean. Low values also occurred with a rainy condition.

Acknowledgement

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한국의 시골지역에서의 오존농도의 특성

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(1994년 8월 31일 접수)

1993년 7월부터 1994년 6월까지 1년간 시골지역에서 지면부근의 오존을 연속적으로 측정하여 5분 평균치를 연구에 이용하였다. 이 관측은 북위 36.4°, 동경 127.6°에 위치한 충북 청원군 강내에서 실시되었으며, 1년 평균값은 17ppb이고 월평균은 6-47ppb이다. 여름에 최대값이 발생하고 겨울에 최소값이 나타나며, 이들은 인위적인 배출물 및 광화학 반응과 관련이 있다. 오존의 일변화는 15:00~16:00시에 최대치와 07:00~08:00시에 최소치가 발생한다. 오존이 80ppb이상 발생하는 기간에는 북-북서풍의 안정한 기류가 유입할때 발생하는 반면, 여름에 오존이 매우 낮게 발생하는 기간에는 북태평양에서 유입되는 기류와 함께 발생하였다. 그러므로 장거리에 근원을 둔 인위적인 대기오염의 이동(LRTAP)이 시골지역의 국지적인 오존의 발생보다 더 큰 기여를 하고 있음을 시사한다.