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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A climatological study of rural surface ozone in central Greece" *by* P. D. Kalabokas and C. C. Repapis

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Replay to comments of Anonymous Referee #1: We would like to thank the referee for the helpful and constructive comments.

General comments

The first phase of this study is published in Atmospheric Environment (Kalabokas et al., 2000). The comparison was based on the 3- year (1996-98) ozone data at the rural station of Aliartos, the 6-year (1990-1996) ozone data at the peripheral station of Liossia and the 3-year ozone data (1992-1995) at the peripheral station of Demokritos. The basic findings of that study were that the seasonal averages of ozone in the afternoon hours (12:00-18:00) are very similar in the three stations at the relatively high levels of 110-120 ug/m3, when in the Athens peripheral stations only data under "strong" (higher than 5 m/s) N-NE winds were considered. In the present APCD paper the data-set of

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the urban peripheral station of Liossia has been extended to 10 years, the data-set of the rural station of Aliartos to 4 years and the corresponding 10 year data-set of the urban background station of Geoponiki has been taken into account.

The practice of the data selection with respect to high wind speed has been already used in the literature (Scheel et al., 1997 and references therein) in order to yield representative boundary layer ozone concentrations even for wind speeds only higher than 3m/s. In order to further eliminate the urban influence and in combination with the fact that "strong" N-NE winds are relatively frequent in the area, the 5m/s average daily wind speed was used as a filter.

For the summer months for which the screening is done, the NO2 levels at the peripheral station of Liossia are by about 35% higher than in Aliartos and in the urban background station of Geoponiki by a factor of 2 higher. From the experimental and geographical data it can be argued that rural conditions can be prevailing in the peripheral station of Liossia under "strong" northerly winds, since the summer NO2 afternoon concentrations are only about 10 ug/m3, which is a value encountered at rural stations in Europe.

The urban background station of Geoponiki is used more as a complementary one to show that despite the greater influence of the urban area the ozone levels under strong northerly winds are at the same level at both stations. The average wind speed for the screened cases in summer is 6 m/s and the distance between the two stations is 10 km. Under such north winds an air mass arrives at the urban background station of Geoponiki on the average 25-30 min (which could be even shorter at mid-day) after having passed Liossia, which is a short time in order to have substantial photochemical production of ozone from the urban emissions injected in the traveling air mass. It seems that, based on low precursor concentrations due to the high dispersion and the short traveling time over the urban area, the amount of ozone produced photochemically in the moving air mass is offset by the destruction caused by the fresh NO emissions.

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The correlations shown in Figures 8 and 10 between afternoon ozone values in Aliartos, Liossia and Geoponiki use similarly screened data (wind speeds higher than 5m/s for all stations). In the comparison of average ozone values between the three stations all values of Aliartos were used, after performing exactly the same test that the referee suggests. In fact, in Figure 6 of the paper Kalabokas et al., (2000), the diurnal ozone profile in Aliartos is shown for summer 1996, with average daily winds at the station higher than 5m/s. It comes out that the summer afternoon (12:00-18:00) averages remain at the 60ppb-120 ug/m3 levels even during "strong" winds. In addition, the nocturnal values are slightly higher, which might be explained by the fact that the nocturnal inversion layer becomes weaker with high wind speeds. Since for the main time period of interest (summer afternoon) there is no change observed, which implies that almost all of the ozone measured in Aliartos is not produced locally, all the Aliartos data were used for the comparison in order to obtain a better statistical significance, since we dispose a shorter time period of measurements in Aliartos than in the Athens stations.

Detailed Comments

Page 4992, line 8 and Page 4993, line 7: There is a misunderstanding on the term "urban background" attributed to the Geoponiki station. The term "urban background" is referred to monitoring stations measuring the average pollution levels of an urban agglomeration and not influenced by strong local sources. The Geoponiki station as it is located at the middle of a University Campus clearly falls in this category. The average annual NO2 Geoponiki values are less than the half of the "street canyon" station of Patission values while the annual NO levels are less than the 1/3 (Kalabokas et al., 1999). The Patission station is also located at the central part of the urban agglomeration of Athens but on a busy commercial street with heavy traffic.

If the comparison of the average NO2 levels between Aliartos and Geoponiki is focused on the summer period, which is the most important regarding the ozone levels, the NO2 levels at Geoponiki are higher than in Aliartos by only a factor of two (Figs. 2,6) while

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in Patission are higher by a factor of almost 5.

Page 4993, line 25: As mentioned in the reply to the General Comments this test has been done in the first stage of this work (Kalabokas et al., 2000).

Page 4994, line 9: The phrase "spatial homogeneity" could be changed to "similar levels".

Page 4995, line 3: The sentence could be removed.

Page 4995, line 7: This has been already answered in the reply to the General Comments and to the Detailed Comments (Page 4993, line 25). It has to be reminded that the correlations shown in Figures 8 and 10 between afternoon ozone values in Aliartos, Liossia and Geoponiki use similarly screened data in all three stations (daily average wind speeds higher than 5m/s, all wind directions included). It could be cited that winds with average daily wind speed greater than 5m/s coming from the N-NE sector are the 80% of the total.

Page 4997, line 18: The authors agree that the wind screening plays an important role but they would like also to point out that the Liossia station is on a mountain slope influenced by mountain breeze during summer nights and on a higher altitude than the other two stations. It has to be reminded that as shown in the paper Kalabokas et al., 2000-Fig.6, the nocturnal ozone levels in Aliartos in summer are only slightly increased with wind speeds higher than 5m/s and does not exceed the 1/3 of the summer afternoon values, implying that the nocturnal ozone destruction at the ground remains important in Aliartos even under "strong" winds.

Page 4997, line 27: "Fig.6" in page 4998, line 1, is removed. The sentence is based on the logical assumption that since the long term seasonal NO2 levels (shown in Fig.6) are higher in Geoponiki that in Liossia the nocturnal levels should follow the same tendency. As shown also in Kalabokas et al., 1999 the 11-year NO2 average at Geoponiki is about the double of the corresponding one at Liossia. Therefore, the

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last phrase of page 4997 and the first phrase of page 4998 are revised as follows: "On the other hand in the urban background station of Geoponiki, which is located at the Athens plain, the nocturnal NOx concentrations are higher than Liossia (Kalabokas et al., 1999), as a result of ozone destruction from fresh NO emissions. Consequently the ozone nocturnal levels at Geoponiki are lower than at Liossia as shown in Figure 3".

Page 5000, line 19: This paragraph could be removed.

Page 5002, line 11: The reference Scheel et al., 1997, which is a paper summarizing the European surface ozone measurements in the framework of the TOR-1 project, is mentioned in the Discussion section (Page 4998, line 13).

Page 5002, line 12: As already mentioned the correlations shown in Figures 8 and 10 between afternoon ozone values in Aliartos, Liossia and Geoponiki use similarly screened data (wind speeds higher than 5m/s for all stations).

Page 5002, line 23: The 12:00-18:00 6-hour averages are used in order to obtain the best representative boundary layer conditions for all seasons. During summer, when violations of the standard are recorded there is almost no difference in the Athens stations between the 12:00-18:00 and 12:00-20:00 averages as shown in Figure 3.

Page 5003, line 1: The paragraphs starting in pages 4996 line 14 and 4999 line 13 including Figure 12 and relevant references are devoted to this important topic.

References

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