Atmos. Chem. Phys. Discuss., 7, S2522–S2526, 2007
www.atmos-chem-phys-discuss.net/7/S2522/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Vertical ozone measurements in the troposphere over the Eastern Mediterranean and comparison with Central Europe" *by* P. D. Kalabokas et al.

P. D. Kalabokas et al.

Received and published: 20 June 2007

Reply to comments of Anonymous Referee 3. We would like to thank the Referee for the helpful and constructive comments.

General comments As noted in the introduction, "The analysis of ozone measurements made around Athens and at a rural site in Central Greece (Varotsos et al., 1993; Kalabokas and Bartzis 1998; Kalabokas et al, 2000; Kalabokas and Repapis, 2004) revealed fairly high rural ozone levels; around 60 ppb during summer". This work is somehow the continuation of the above-cited research. Its scope is to describe the distribution and the characteristic variations of the vertical ozone profiles, especially in the lower stratosphere, in order to give more insight to the observed high summer

rural ozone levels in the area. The MOZAIC profiles used consist the largest data-set of summer ozone profiles available in the area (Aegean Sea and the north coast of the Eastern Mediterranean). They are high quality measurements and, as being part of a global network, they can be easily compared with the corresponding measurements in other regions worldwide. The parallel examination with the corresponding (quasi-simultaneous) measurements in Central Europe has been made essentially in order to examine the influence on the ozone concentrations throughout the troposphere of the, already reported in the literature, atmospheric outflow from Eastern and Central Europe towards the Aegean and the Eastern Mediterranean area during summer (long-range transport of ozone and its precursors in the area or the subsidence of the richer in ozone upper tropospheric layers to the boundary layer). In addition, the Central European region, as being more studied than the Eastern Mediterranean could be used as a reference for comparison when examining the ozone variations at the various tropospheric levels in both areas. Finally, in order to assess the role of meteorology on the tropospheric ozone levels, the characteristic meteorological conditions of the days with the highest and the lowest ozone mixing ratios have been also investigated in both regions while the primary focus was on the Eastern Mediterranean. It has to be kept in mind that similar measurements (vertical ozone profiles at rural sites) are very rare in this region.

The last paragraph of the introduction will be modified according to the remarks of the above paragraph.

Specific comments

Abstract, line 7: The difference of ozone values between the Eastern Mediterranean and Central Europe is significantly enhanced in the lower troposphere (20-40%) in comparison to the middle and upper troposphere (5-10%).

Introduction (1): In most of the referenced papers in the introduction high surface and boundary layer ozone values are reported at rural sites around Athens, in Central

ACPD
7, S2522–S2526, 2007

EGU

Greece and in the Aegean area, exceeding frequently the EU Air Quality standard for human health protection. The case of long-range transport of ozone and its precursors from Eastern and Central Europe towards the Eastern Mediterranean has been discussed in some of these publications. The findings of two major intensive campaigns (MINOS and PAUR), which took place in the area during the recent years and report some vertical ozone measurements, have been included in the introduction. This paper analyzes the ozone MOZAIC profiles in the area, which, to our knowledge, constitutes the largest dataset of its kind (77 profiles), collected during the summer months over a 7-year period (1996-2002). The analysis of these measurements leads to more representative summer average profiles under the major weather patterns prevailing in the region and tests the hypothesis of the photochemical ozone production in the lower troposphere associated with long-range transport of pollutants originating from Central or Eastern Europe, already reported in the referenced research work. In addition to the reporting of the major literature results in the introduction, the most representative papers are also mentioned in the Results and Discussion section, in relation to the findings of this paper.

Introduction (2): At first the phrase in the introduction “long term ozone measurements” has been changed to the more appropriate in this context “ozone measurements”. The two papers, which mention the lack of long term monitoring of surface ozone in the Eastern Mediterranean, are referenced in order to underline that this region is much less studied than Central Europe or Northern Europe by the middle of the previous decade. Indeed, long-term rural surface ozone monitoring in the area started at the end of the 90s as mentioned in the paper and also in the referenced papers Kouvarakis et al., 2000 and Kalabokas et al., 2000. MOZAIC data do not substitute, by no means, the long-term monitoring. They are complementary to surface ozone data and they are valuable because, as already discussed, very few ozone profiles exist in the area in order to study the vertical tropospheric ozone distribution and the measurements are extended in the summer months of the 7-year period (1996-2002).

ACPD

7, S2522–S2526, 2007

Usually the term “rural” ozone is used in the paper although sometimes the term “background” ozone is also employed like in the mentioned paragraph at the end of the introduction. Both terms describe the existing surface and boundary layer ozone concentrations measured at rural (non-urban) sites and which are not directly influenced by local urban centers. As mentioned in the second paragraph of the introduction the typical summer rural ozone levels upwind of the major urban center of Athens are around 60 ppb exceeding frequently the EU human health protection standard. In the literature papers mentioned in the introduction the atmospheric processes determining the background ozone levels are reported, especially in Volz-Thomas et al., 2003 (a review paper). The main factors are a) down flow from the higher tropospheric layers and b) photochemical production and transport in the boundary layer. As mentioned above the lack of vertical ozone profiles at rural sites in the area give additional value to the presented MOZAIC profiles. The vertical ozone profiles are important in order to distinguish the influence of the higher tropospheric layers to the boundary layer. The separation of the profiles into high and low ozone days was made in the purpose of determining the meteorological conditions leading to high and low boundary layer ozone in the area, as mentioned in the last paragraph of the introduction. Regarding the “rural” or “background” ozone levels resulting from the analysis, it comes out that they are significantly higher during the periods that the northern flow over the Aegean prevails than when the Middle-East low is extended towards the examined area inducing western atmospheric circulation.

Methods: As ozone distribution is quite well-studied in Central Europe, this area could be used as a reference to the Eastern Mediterranean. Given the frequent summer northern flow from Eastern and Central Europe towards the Eastern Mediterranean, the comparison of the “quasi-simultaneous” ozone profiles between the two areas could indicate the origin of the relatively high rural ozone levels in the boundary layer of the Eastern Mediterranean and in particular if it comes mostly from down flow from the higher tropospheric layers, richer in ozone, or to boundary layer processes (photochemical ozone production associated with long range transport). As observed in Fig.

ACPD
7, S2522–S2526, 2007

EGU

8 both factors seem to contribute to the high ozone levels, the boundary layer processes being more predominant.

The CO vertical profiles (extremely rare in this area) could help the interpretation of the vertical ozone distribution, especially after the separation into high and low ozone days. As observed in Fig. 7, higher CO values are measured in a high ozone day (August 25th, 2002) and lower CO values in a low ozone day (July 28th, 2002) suggesting that high ozone concentrations are associated with high levels of ozone precursors and photochemical ozone production in the lower troposphere. The same observation is made if we compare September 22nd, 2002, a day with relatively high ozone values and September 15th , 2002, a day with low ozone values (not shown in the paper). Our opinion is that the presented CO measurements are valuable for the analysis of ozone profiles but also as new information, although more CO profiles would be necessary in order to determine the representative CO values over the area.

Results, Section 2.4: As observed in Fig. 2a during the high ozone days, when the northern flow is established in the Aegean, high pressures prevail over the Balkans from where originate the air masses participating in the northern flow. As mentioned in section 2.4 downward fluxes of air masses are expected during anticyclonic situations. The corresponding paragraph has been rephrased.

Figures: The exact coordinates of the measurement locations are mentioned at the beginning of the results and discussion section.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 2249, 2007.