

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

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Reply to comments of Anonymous Referee 2. We would like to thank the Referee for the helpful and constructive comments.

1). General comments: The number of the MOZAIC ozone profiles in the summer period (June-September) of each year from 1996 to 2002 is 28, 10, 0, 12, 2, 12, 13. The forest fires in Greece from the year 1996 to the year 2002 were (in hectares burnt) 25310, 52373, 92901, 8289, 145033, 18221, 6013 (Schmuck et al., 2003). From the above it comes out that most of the profiles have taken place in the year 1996, while in 1998 no profiles have been taken and in 2000 there were only two profiles. For the remaining years 10-13 profiles per season were recorded. Therefore, for the two worst

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years of forest fires in Greece (1998 and 2000) only two ozone profiles exist. If these profiles are excluded from the analysis, the ozone mean levels in the lower troposphere become lower by only 0.2-0.3 ppb. Therefore the data-set is not expected to be skewed by extreme events of forest fires. In addition, comparable summer ozone levels have been measured in the area with no significant influence of regional biomass burning as indicated from parallel methyl bromide measurements (Lelieveld et al., 2002). As mentioned above, 2002 was the year with the least forest fires in Greece for the period 1996-2002 and therefore the biomass burning influence from local sources should be minimal on that particular year (also in Bulgaria moderate forest fires have been recorded as reported by Schmuck et al., 2003).

The year 2002 was selected because CO is measured in MOZAIC since 2002 and on that year there were 6 CO profiles available for the north coast of the Eastern Mediterranean. It has to be emphasized that very few CO profiles exist in this region and that the two profiles are shown as representative of high and low ozone days while similar features are observed in the other profiles. The profile corresponding to the highest ozone day is presented in order to show the CO distribution in the lower troposphere. The 260 ppb surface CO value on that day could be possibly due to biomass burning but it has to be mentioned that CO values higher than 150 ppb have been reported in the boundary layer over the Aegean without significant influence of biomass burning (Lelieveld et al., 2002). Concerning the ozone profiles of the year 2002 they were well distributed between the high and the low ozone days. As it is shown in a latter paragraph of this reply, the average differences between high and low ozone days over Rhodes are quite close to the corresponding mean differences of the entire data-set especially inside the boundary layer where the attention is more focused.

A summary of the above observations will be incorporated into the manuscript

2). Specific comments p. 2252, l 9: Since 1994, within the framework of the MOZAIC program (Marenco et al., 1998) five commercial airliners have been equipped with instruments to measure ozone, water vapour, and carbon monoxide (since 2002). One

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aircraft carries an additional instrument to measure total odd nitrogen (since 2001). Measurements are taken from take-off to landing. Based on the dual-beam UV absorption principle (Thermo-Electron, Model 49-103), the ozone measurement accuracy is estimated at $\pm[2 \text{ ppbv} \pm 2\%]$ for a 4s response time (Thouret et al., 1998). Based on an infrared analyser, the carbon monoxide measurement accuracy is estimated at $\pm[5 \text{ ppbv} \pm 5\%]$ for a 30 s response time (Nedelec et al., 2003).

p. 2253, l 11: Antalya is located outside the Aegean channel deep in a gulf surrounded by high mountains and was not expected to be influenced the same way by the predominant summer northern flow as the other two stations. p. 2254, l 28: Indeed the anticyclone is located in Eastern Europe (Fig. 3a). Nevertheless, the flights connecting Vienna to Eastern Mediterranean (90% of the total) should be influenced by anticyclonic conditions, as Vienna is located at the edge of the anticyclone. On the other hand in Fig. 3b a low-pressure system is installed in Eastern Europe influencing also Vienna, during the low ozone days. -section 2.2: Fig. 2a shows the composite map of the highest ozone cases in the Eastern Mediterranean (not in Central Europe). As shown in the map apparently Vienna and Frankfurt are not influenced by the high pressure system, They are influenced by the “rather strong airflow driven by the Scandinavian low” (p. 2254, l.14). Fig. 3a describes the meteorological conditions leading to high ozone cases in Central Europe and as noted in the previous remark (p. 2254, l 28) the flights connecting Vienna to Eastern Mediterranean (90% of the total) are expected to be influenced by the Eastern European anticyclone.

p. 2255, beginning of section 2.3: Fig. 4 will be referenced at the end of the paragraph.

p. 2255, lines 20 ff: As mentioned also in the General Comments, the year 2002 was selected because CO profiles are also available only on that particular year and the ozone profiles were well distributed between the high and low ozone days. The average ozone differences between high and low ozone days over Rhodes for each 100 hPa layer from 1000 hPa to 400 hPa were (in ppb): 15.6, 25.9, 21.7, 22.9, 16.6, -0.5, 10.7. The corresponding average ozone differences for the profiles over Heraklion were

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20.6, 24.0, 24.9, 25.7, 20.3, 14.9, 21.8 and over Antalya were 15.4, 18.5, 3.8, 5.2, 7.0, 25.9, 28.5. Finally the corresponding differences for the total number of profiles were 15.0, 22.8, 15.4, 15.1, 12.1, 14.1, 18.7. From the above it comes out that the average ozone differences between high and low ozone days over Rhodes are quite close to the corresponding differences of the entire data-set especially inside the boundary layer where the attention is more focused. Concerning the other airports, the differences in Heraklion are quite similar to those of Rhodes up to the 600 hPa pressure level. The Antalya flights show comparable differences with the other two airports inside the boundary layer but the differences are smaller in the 800 - 600 hPa region due probably to the fact that Antalya is located outside the Aegean Channel deep in a gulf surrounded by high mountains. A summary of the above observations will be included into the text.

p. 2255, lines 28 ff and p.2256; line3: For the determination of the air mass origin, we use the FLEXPART Lagrangian particle dispersion model (version 6.2, Stohl et al., 1998, 2005). FLEXPART was driven by model-level data from the European Centre for Medium-Range Weather Forecasts (ECMWF), with a temporal resolution of 3 hours (analyses at 0000, 0600, 1200, 1800UTC; 3-hour forecasts at 0300, 0900, 1500, 2100UTC), and 60 vertical levels. Horizontal resolution was $1^\circ \times 1^\circ$ globally. 20000 particles were released from grid boxes ($0.5 \times 0.5^\circ$, 100m in height) centered on the MOZAIC profiles. The particles were advected backward in time over 10 days. Particles were transported both by the resolved winds and parameterized subgrid motions. FLEXPART parameterizes turbulence in the boundary layer and in the free troposphere by solving Langevin equations (Stohl and Thomson, 1999). FLEXPART uses also a parameterization scheme for convection (Forster et al., 2007). The residence times of particles were output every 3 hours as 3-hour averages. They are available at a grid spacing of $1 \times 1^\circ$ in 3 layers between 0 and 2km, 2 and 4km, 4 and 20km. Percentage contribution of a geographical area to the chemical concentration of a box centered along a MOZAIC profile is calculated by dividing the total residence time of the 20000 released particles found in the area by the total residence time in the whole output grid over 10 days.

p. 2256, figures 5 and 6: The scale has been modified. For the other remarks, see previous paragraph.

p. 2256, line 28: As discussed also above the possible influence of forest fires in the CO concentrations will be mentioned in the text.

p. 2257, lines 4ff: For the existing CO profiles there are parallel ozone measurements. In relation to the backward simulations (performed for the high and low ozone days of the year 2002) as mentioned in the text, “One CO profile falls into the group of the highest ozone quartile (August 25) and two CO profiles fall into the group of the lowest ozone quartile (July 28 and September 15)” (p. 2257, lines 5-7).”

p. 2257, line 15: The paragraph has been rewritten following the remarks of the other reviewers. The similarity is argued for the 900-400 hPa pressure levels where parallel increases and decreases of ozone and CO between high and low ozone days are observed. Close to the ground ozone is expected to be destroyed, as all Rhodes profiles were taken in the early morning hours. Concerning the assessment of the high CO surface value, it has to be mentioned that on that particular day there are no reports of fires in Greece. The second highest surface CO value (at 170 ppb) was recorded on September 22, 2002 with corresponding 900 hPa ozone at 58 ppb, a high value for this period of the year. The northern flow was established in the Aegean during both profiles and the coastal airport of Rhodes is well exposed to this circulation excluding the local influence and indicating medium or long-range pollution transport in the boundary layer. As mentioned in the general comments CO values higher than 150 ppb have been reported in the boundary layer over the Aegean without significant influence of biomass burning (Lelieveld et al., 2002). For a more accurate assessment of the CO values more CO profiles would be necessary.

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