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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.

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Reply to comments of Anonymous Referee 1. We would like to thank the Referee for the helpful and constructive comments.

General comments: (1)-(2): 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 while the corresponding surface air temperatures (National Observatory of Athens) were: 25.6 oC, 25.9 oC, 27.6 oC, 27.9 oC, 27.8 oC, 28.0 oC, 26.9 oC. Therefore, most of the profiles (28) have taken place in the year 1996, while in 1998 no profiles were taken and in 2000 only two profiles. For the remaining years (1997, 1999, 2001, 2002) 10-13 profiles per season were recorded. The June-September period 1998-2001 in

Greece was warmer than the years 1996, 1997 and 2002. Only the 1/3 of the profiles has taken place during the warmer period

The 1996-2002 average monthly surface air temperatures at the National Observatory of Athens from June to September were: 26.6+/-0.7oC, 29.3+/-1.2 oC, 28.5+/-1.4 oC, 23.9+/-1.2 oC while the average daily temperatures of the MOZAIC profiles days for the corresponding months were: 26.5+/-2.7 oC, 29.1+/-2.6 oC, 28.9+/-2.5 oC, 24.0+/-2.9 oC. From the above it comes out that the weather conditions during the profiles days are quite representative of the examined period 1996-2002.

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). The annual precipitation in Athens from the year 1996 to the year 2002 was: 423.1mm, 384.0mm, 490.0mm, 468.3mm, 227.9mm, 382.5mm, 987.3mm while the corresponding summer (June-September) precipitation was: 31.4mm, 23.5mm, 5.7mm, 70.2mm, 17.5mm, 15.9mm, 361.3mm. From the above it comes out that only two ozone profiles have been taken on 2000 and none on 1998, the two worst years of forest fires in Greece. 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 in the lower troposphere. 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). Concerning possible periods of droughts, it has to be mentioned that the Mediterranean climate is characterized by dry summers. The driest summer for Greece was 1998 followed by 2001 and 2000. 2002 was an exceptional wet summer and the 90% of the precipitation was concentrated on 5 major rain events (July 7, August 18, September 3, September 5 and September 8). There are no MOZAIC profiles during these days of extreme rainfalls.

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

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(3). It will be answered in the Specific Comments.

2). Specific comments p. 2252, l 9-16: The answer is already given above in the General Comments section.

p. 2253, l 11-15: 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. The major boundary layer process implied could be the ozone production in the boundary layer through photochemistry, which is a reasonable hypothesis that might explain the observed higher ozone differences inside the boundary layer in comparison to the upper levels. Several authors mentioned in the introduction of the paper have already reported the above argument.

p. 2253, l 15-25: As shown in the reply to the general comments, the weather conditions during the days of measurement seem to be quite representative of the whole period as they are well distributed between colder and warmer years.

p. 2254, l 1-5: The construction of composite (average pressure fields of selected days) weather maps is a relatively frequent practice in Meteorology and Climatology As mentioned in the paper the procedure for the construction of NCEP/NCAR composite weather maps (mean or anomalies), based on reanalysis maps (2.5 x 2.5 degrees grid) is given in the paper of Kalnay et al., 1996. Additionally, the handbook “Synoptic climatology in environmental analysis”, by Brent Yarnal, (In: Studies in Climatological series, Eds. Prof. S. Gregory, Belhaven Press, London and Florida, 1993), where a general description of the procedure of composing maps is done in Chapter 5, could be suggested for more general information on the subject. An explanatory phrase on NCEP/NCAR maps will be added in the text.

p. 2254, l 10. The average daily temperature (at the National Observatory of Athens) for the group of the high ozone days was 28.6 oC, while for the low ozone days the corresponding value is 24.7 oC. The average deviation of the daily temperatures from

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the corresponding monthly temperatures for the highest ozone quartile is 1.0 oC and for the lowest ozone quartile is -0.7 oC. From the above it comes out that higher temperatures are recorded during the high ozone days.

p. 2255, l. 9-15: The paragraph will be rephrased according to the suggestion.

p. 2255, l. 20-25: It has been shown in the General Comments discussion that the meteorological conditions during the 2002 measurements were quite representative of the whole data-set. In addition, the ozone differences between the maximum and minimum ozone days at Rhodes (all in 2002) are comparable with the corresponding differences at Heraklion (most 1996 profiles).

p. 2256, l 1-3: 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 Center 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°x1° globally. 20000 particles were released from grid boxes (0.5x0.5°, 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 1x1° 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, l 29-30: As given in a previous paragraph of this reply, 2002 was the year

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with the least forest fires in Greece for the period 1996-2002 (Schmuck et al., 2003) and therefore the biomass burning influence should be minimal on that particular year. The remarks of the reviewer will be included in the paragraph. As mentioned in the text though, high CO and ozone values have been reported from previous studies in the area without significant influence of biomass burning (Lelieveld et al., 2002). In any case, high CO values at rural sites indicate that long-range pollution transport originating from combustion sources (anthropogenic or biomass burning) takes place in the area.

p. 2257, l 15-18: The phrase could change according to the remark. What is meant is that below the 600 hPa down to 900 hPa level the observed increase in the average ozone difference between high and low ozone days is accompanied by corresponding increases in the concentrations of the CO profile during the highest ozone day.

p.2257, l 15-30: The suggested rephrasing of the paragraph will be incorporated into the text.

p.2258, l 15-17: The key factors are expected to be the primary pollutant emissions (anthropogenic, biogenic or biomass burning) in the Eastern and Central European continent, which travel southwards with the predominant northern flow. These pollutants under the intense summer sunshine are expected to be precursors of photochemical ozone. In fact, according to recent measurement and modeling studies mentioned in the paper, polluted air masses exported from Central Europe towards the Mediterranean in summer exhibit high ozone production rates. The above remarks will be incorporated into the discussion section.

3). Technical Comments All suggested corrections will be incorporated into the text.

References

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