Atmos. Chem. Phys. Discuss., 10, C4241–C4248, 2010
www.atmos-chem-phys-discuss.net/10/C4241/2010/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Ozone over the Western Mediterranean Sea – results from two years of shipborne measurements" *by* K. Velchev et al.

K. Velchev et al.

jens.hjorth@jrc.it

Received and published: 18 June 2010

We would like to thank the referees for their constructive comments. Based on their inputs, we intend to produce an amended version of the paper.

In the following we will address the referees comments one by one:

Referee 1:

The referee finds that the objective of evaluating the relative impact of long range transport and local sources "are somewhat forgotten when discussing the data". We did not forget this objective, but clearly the kind of analysis we did of the data (based on inspection of composite meteorological maps and calculation of back trajectories) does not allow to give quantitative estimates of the contributions of different sources. The con-

clusions we present regard the synoptic situations that cause high ozone concentrations and the transport patterns found in these situations; they highlight the importance of subsidence of ozone rich air and of breeze circulation, as explained in the paper. For the area investigated in this study, 'high ozone' situations are mainly found in situations where the ozone rich air masses have circulated within the Mediterranean Basin for several days, as described in the paper, and this, of course, favours the contribution of local sources. We believe that the conclusions that the paper reaches provide relevant information about the phenomenology of Mediterranean ozone and its sources.

We think that the reviewer is right when he points out that a mesoscale model would have been a useful tool for a more quantitative analysis of the data; unfortunately such a model was not available. In a revised version of the paper we will provide a more detailed discussion of published mesoscale modeling of ozone in the Mediterranean basin in relation to the present data set.

We agree on the suggestion to provide a scatter plot of O3/BC as this would provide evidence of the 'ageing' of the air mass. However, it should be noticed that it will not tell whether this ageing took place in a circulation pattern within the Mediterranean Basin or during transport from e.g, more northerly parts of Europe. For what concerns other aerosol-related analyses, we would prefer to present that in a second paper (under preparation).

(We will discuss the general comments that the reviewer makes on Section 3 and 4 in the detailed discussion of these sections).

Section 2, Method:

The question of avoiding contamination from the ship is of course important, but the procedure that was used is actually described in the paper (Section 2.3).

Aerosols were filtered at the ozone inlet by an aerodynamic PM1 sampling device.

We did consider also BC data as an indicator of pollution from the ship.

We will provide more detailed information about the experimental procedure in the revised version of the paper (including a plot illustrating when we have daytime and nighttime along the route of the ship, as requested) .

Section 3

The discussion related to Fig. 6 was included because we found that the data nicely illustrated the effect of the sea breeze near a city. We recognize that this phenomenon has been discussed previously in the literature, so we can remove this part of the paper or limit it to a short statement about these observations in order to give priority to other aspects.

As the main part of the observations over the sea are done during evenings and nights, it is important to understand to which extent that influences the observed ozone levels. We have done that by looking at the diurnal variations observed on EMEP monitoring stations on islands in order to estimate their magnitude. The referee suggests to do that by looking at the observations on the ship, but the problem here is that the ship is moving and the change of geographical location has an influence on the ozone concentrations which we cannot distinguish from the day-night variation. E.g. looking at the 24 hours leg from Tunis to Palma de Mallorca, we do not see a significant ozone decrease during night or increase during daylight hours, so other influences are more important here.

Fig. 3 provides an overview of the data and shows the high degree of similarity between the average ozone concentration profiles between the two years, thus we find that it is worthwhile to show this figure. However, it seems a good idea also to provide a table with statistical information about the data, showing averages and extreme values, as suggested by the referee.

We recognize that the plots on Fig. 4 are too small, we will present them differently in a revised paper. Apart from that, we believe that these plots are useful for providing a picture of the seasonal variation and the areas where extreme values are found.

The referee makes several suggestions regarding how to focus the data discussion. We agree that a BC/O3 scatter plot will be useful. Also the effects of diurnal effects along the coast represent a relevant issue, however, as mentioned above, the data set has a limitation given by the fact that the observation point is moving, which makes a discussion of diurnal variations outside of harbours very speculative. One of the reasons for focusing most of the discussion in the paper on the open sea leg between Tunis and Palma de Mallorca was to minimize the influence of the large day-night variations found over land.

Section 4

The referee asks for a critical analysis of the met data used for describing the regional scale circulation in the Mediterranean basin. Although not presented in the paper in any detail, we have actually done this kind of analysis, which will be included in a revised paper. We have analyzed the weather maps (synoptic Europe by DWD, and regional from BOLAM model analysis fields : pressure, wind , temperature, humidity) for the cases with high ozone. All maps revealed a similar pattern of the meteorological situation over the Western Mediterranean, this situation is typical for an anticyclone. The horizontal dimension of this baric field is about 1000 km. Because of this dimension it is possible to use NCEP reanalysis, usually used for synoptic analysis. We suppose that the mesoscale breeze circulation, very pronounced in the western Mediterranean, has significant impact on the synoptic scale. The crude methodology with coarse grid reanalysis field gives the possibility to identify the already established anticyclone. Using a mesoscale, finer grid, models it would perhaps be possible to follow the formation and evolution of the anticyclone.

We have made a rather detailed discussion of the relation between synoptical situations and ozone levels with an emphasis on the conditions favouring high ozone concentrations. The referee finds that the discussion is too lengthy. We think that the analysis in this chapter goes beyond what has been presented previously in the literature and thus represents an original contribution which has to be presented in some detail. However (taking into consideration also the comments by Referee 2) we realize that the readability and clarity of the text should be improved as well as the connection between text and figures shown.

It is correct, as pointed out by the referee, that subsidence may also bring down air with low ozone and our analysis does not exclude that this may take place. The point we make is that for the episodes with 'high' ozone (> 60 ppbV, appr. corresponding to the 25% percentile of the data) strong subsidence is a common feature.

A lagrangian transport model would, as suggested by the referee, be a useful tool for investigating the effectiveness of different transport pathways. Unfortunately we do not have the possibility of carrying out such simulations.

Trajectory section:

The referee finds that this section is 'rather weak' because the trajectories for high ozone concentrations show several different transport pathways. The scope of these trajectory calculations was to look into the reasons why high ozone values were repeatedly found in some parts of the route of Costa Fortuna and see if this could be explained by the influence of particular precursor source areas. The results indicate that the ozone 'hot spots' are the result of contributions from several different source areas. This is a 'weak' conclusion in the sense that it will certainly not produce any newspaper headlines, but we believe that it gives a correct description of the situation.

We are aware that trajectories at low altitudes calculated with a large scale wind field have large uncertainties. However, as mentioned in the paper, calculations with two independent meteorological data sets gave rather similar results, so we find that the trajectories are useful for a qualitative evaluation of the data.

We agree that it would be relevant also to discuss the timing of the trajectory position with respect to the known emission sources.

Technical details:

We recognize that the figures mentioned by the reviewer need to be made more readable.

The trajectories have one point for every 6 hours.

Referee 2:

We agree with the referee that it would be useful to have a figure illustrating day and night measurements done along one single cruise leg. For further discussion of diurnal variations: see answer to Referee 1.

The referee complains about the painfully small characters in the labeling of some figures; we recognize that this needs to be changed.

The referee finds that the descriptions of the meteorological situations are difficult to follow. We will try to make this part of the paper more readable in the revised version of the text. A main point in the analysis we present is that the circulation pattern over the Western Mediterranean can be explained by the combined effect of the breeze circulation along the coast and the large scale pressure centres in the surroundings.

The referee finds that it is not clear how the different characteristics of the anticyclones, discussed in the paper, influence ozone distributions. We cannot provide an answer to this question, we find high ozone concentrations under different types of anticyclonic conditions. The reason for discussing different types of anticyclones is to address the particular mechanisms involved in the formation of anticyclonic meteorological situations in this area.

The referee mentions that the composite map of Fig. 8 does not show clear differences between the 'high' and the 'low' ozone conditions. Fig 8 shows the maps for the vertical velocity at 1000 hPa (near surface level) for the "high" and "low" ozone groups. The large scale distribution (looking at the whole Mediterranean Sea) is similar for both groups and is generally characterized by upward motions in the Western part (over Spain and Northwest Africa) and downward motions over the Eastern Mediterranean.

However, focusing on a smaller scale over the central part of the Western Mediterranen Sea , differences in the sign of the vertical velocity between the two maps can be noticed, i.e. dominant downward motion for the high ozone episodes while upwind motions are prevailing for the low ozone group. These differences remain also for altitudes up to 850 – 700 hPa (composite maps not shown), suggesting that the atmospheric circulation in the central part of the West Mediterranean Sea plays a significant role. Trying to reveal these circulations, the composite maps have been analysed in vertical cross-sections (Fig. 9 and 10).

The referee has a comment to Fig. 10, he is surprised that the diurnal cycle generated by the breeze circulation occurs at such a large scale that it can be described by a rather coarse model. We agree that the scale is larger than the characteristic scale of breeze circulation discussed in several papers in the literature. Again, we see this feature as the result of the combined effect of breeze circulation along the coasts and a high pressure centre over the Western Mediterranean.

Referee 2 asks for having generally a visual connection between the features discussed in the text and the meteorological maps. We find that this is an excellent idea that we will follow when we make the revised version of the paper.

More specifically the referee asks if the "large scale anticyclone" interacting with the "regional summer anticyclone" can be identified in Fig. 7? The figure shows composite maps (i.e. averaged pattern) of the geopotential at two isobaric levels , so they represent the result of this interaction. The interaction could be made more transparent by looking on a single case and the pressure evolution in time. Indeed, studying such interaction alone would be enough work for a separate paper, but we will try to give hints related to this type of interaction using better and/or additional maps in the revised paper.

The referee finds it difficult to identify the starting point of the back trajectories in Fig. 12. Actually each trajectory has a different starting point, placed at the center of the

leg where the high concentration was measured.

We will make an effort to improve the clarity and readability of the discussion of the meteorological features, as solicited by the referee.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 6129, 2010.