Reviewer 2 Comment

The paper highlights one of the important factors, i.e. synoptic meteorological system, controlling high ozone concentration episodes over Western Mediterranean (W-MED) and Central Europe (C-EU), during spring. The text is generally well written and clear. The time series plots of the observations clearly confirm there were two episodes in which ozone builds up during late April and early May in 2008 over most of the Mediterranean countries. However, when it comes to the proof of the argument, there are a number of statements and images repeating the same messages. The analysis of various parameters that are generated from different types of observations and models is a great idea, but unfortunately they are not always univocal. Therefore I think this paper needs a major revision. Particularly, I would encourage the authors to avoid misinterpreting the results of multiple sources.

The major concern I have with this paper, particularly in the result and discussion section, is that there is no clear focus on the two regions which are mentioned in the title (i.e. W-MED and C-EU). The NCEP/NCAR reanalysis maps (geopotential height, etc.) include enough evidences to confirm the existence of subsidence over those (two) regions during late April and early May, respectively. Also, there is a positive signal in all selected meteorological parameters on episode days; however the signal is not as strong as expected for some of the parameters. I cannot understand why the authors avoid focusing on them. Furthermore, the mechanisms leading to ozone enhancement as a consequence of high pressure systems should be explained in more detail. One mechanism could be the accumulation of surface ozone which is produced through chemical reactions due to the stagnant air flow. Another one could be linked to ozone flux from the upper troposphere to the surface, which the authors have already tried to prove but without sufficient arguments.

Authors Response (in Italics)

We would like to thank the reviewer for his comments, which help improving the paper. We think that it would be more practical to structure our response, presented below, according to the very detailed comments of the reviewer.
The corresponding changes in the revised manuscript are highlighted in green color.

Detailed comments:
1) Abstract: “ozone measurement from countries surrounding Western Mediterranean. . .”_The promising title indicates that the study is focused on two different regions, W-MED and C-EU. Then in the abstract the focus changes to only one of them i.e. W-MED. Even the time series are plotted just for W-MED, why? According to the EEA-AirBase maps, Fig.18, the second episode is located over C-EU, isn’t it? Wouldn’t it be better to select a few stations from C-EU and plot their time series for them (as it has been done for W-MED)?

In fact the region of study is the W-MED and the corresponding EMEP stations in that region have been selected for both episodes with highest ozone values over the region. At a later stage of the analysis it came out that especially for the May episode high ozone levels have been also recorded at Central Europe at the same time and for that reason this region was added also to the title. We could add another Figure presenting measurements from some selected Central European stations but this would be in conflict with the remarks of Reviewer 1 who suggests to reduce substantially the number of Fig and which will be reduced to the half of their original number. In addition, the presented EMEP stations in Switzerland and France cover also some parts of the central European domain. For this purpose, also, we will add in the text the stations names as well as geographical coordinates. As a final precaution and for avoiding confusion, we will remove form the title “Central Europe” as the paper is essentially concentrating on the W-MED.

2) Abstract: “the results show that high ozone . . .” _I think here you mean the results of the observation, don’t you?

Yes, indeed. The phrase will be modified accordingly (“results” will be replaced by “observations”).

3) Abstract: “over these areas, strong...”_I think it is too much detail for the abstract section.

This part of the abstract will be reduced according to the reviewer’s suggestion by removing 3 lines from the abstract text (“Over these areas……500hPa pressure levels”).

4) Introduction: in general the strongest focus of this part is over E-MED region during summer.

Yes, indeed. As mentioned, our initial focus was the Mediterranean basin where the highest ozone observations are observed in its Eastern part during summer and, in fact, a major finding of this paper is that comparable synoptic meteorological conditions exist between EMED in summer and WMED in spring during ozone episodes. According to the reviewer’s suggestion, some more elements on previous studies on the WMED will be added.

5) Introduction: “transport times are typically shorter. . .”_wouldn’t it be better to rephrase this sentences to something like “they can be transported over longer distances than that in the boundary layer”?

This phrase will be modified according to the reviewer’s suggestion.

6) Introduction: are there any references regarding the frequent existence of anticyclone condition over MED during spring?

When examining the average seasonal climatological charts of geopotential heights, it is clear that the N. African anticyclone is progressively extending and moving towards the Central Mediterranean when passing from winter to spring and summer months (http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl).

7) Data and methodology: I think it would be nice to add the path (precise address) of the data center or website which the data are taken from.

The precise address of the data center or website from which the data are taken will be added in the text, according to the reviewer’s suggestion (http://www.nilu.no/projects/ccc/onlinedata/ozone/).

8) Data and methodology: what is the horizontal and vertical resolution of the CHIMERE model?

The current configuration of the CHIMERE model uses a horizontal resolution of 0.25° x 0.25° and 30 hybrid (σ,p) vertical levels are used to describe the whole troposphere (i.e from the ground to 200hPa).

9) Data and methodology: the description of methodology is insufficient.

An effort will be made to improve the methodology section and for that purpose a sentence will be added at the end of this section (“The satellite…..boundary layer”).

10) Results and discussion, section 3.1: as it has been mentioned in this part, Fig. 1 (lower panel) shows a very good agreement between the results of different stations. So I cannot see the reason of having two different time series plots in Fig. 1?

Just to show that the regional ozone episodes affect more WMED countries (Spain +Malta), covering most of the basin. It would be difficult to show that without Fig.1a. Especially for the April episode, Malta shows the highest ozone concentrations over several days, attributed mainly to tropospheric transport.

11) Results and discussion, section 3.1: the title of this section is “. . . over Western Mediterranean”, but the description mixes both episodes together. I would strongly recommend the authors to create a separate time series for each episode in each region as it has been done by airbase maps (lowest panel of Fig. 9 and Fig. 18).

These maps and time series are enough proof for the confirmation of the existence of two episodes over these regions.

At first, as mentioned also above, "Central Europe" will be removed from the title as the paper is mainly focused on the Western Mediterranean ozone episodes although Central Europe is in fact also influenced at the same time, especially during the May episode. The selected April and May episodes seem to be the most characteristic of the season but we think that it is worth it to show also the other high (or low) ozone episodes occurring during spring 2008 and showing that mid-day ozone concentrations might have the same variation pattern even at large distances between rural ozone stations, which indicates regional episodes. In addition, due to strong objections from reviewer 1 we need to reduce substantially the number of Figs, which have been reduced by about the half of their initial number.

12) Results and discussion, section 3.2: since there are too many plots, I would suggest the authors to keep the plots related to the episode days in the main paper and move the others (i.e. the plots which they are related to the a few days before episodes) to the supplementary.

It will be done so, following also corresponding remarks of reviewer 1, as about half of the plots will be moved to the Annex.

13) Results and discussion, section 3.2, a): is there any necessity to explain the low pressure system over another region i.e. E. Europe? How this system leads to high ozone concentration over W-MED?

In fact one of the main points of the paper is that the interaction of high and low pressure systems create conditions of subsidence, especially at the interface of both meteorological systems. So, the extent and the intensity of high and low pressure systems are very important for a better understanding of this phenomenon. A key point is that the WMED area is influenced by this process as the air masses arriving there originate from the subsidence area located in E. Europe.

14) Results and discussion, section 3.2, b): why do the authors describe negative specific humidity over Atlantic or etc.? The main focus of this part must be over WMED and there is strong signal of negative specific humidity over this region (in the lowest panel of Fig. 2), why don't the authors concentrate on that?

Essentially for the same reasons as in the previous remark. The extended subsidence over the Atlantic affects WMED through transport as back-trajectories and the meteorological charts show.

15) Results and discussion, section 3.2, c): do we really need different maps of omega and its anomaly? In fact, both of them have the same messages.

We wanted to put more emphasis that during the ozone episodes, unusual vertical exchange conditions occur (positive omega, indicating subsidence). The omega anomalies could be removed from the main Figure list, also in the spirit of the remarks of reviewer 1 for reducing the total number of Figs.

16) Results and discussion, section 3.2, d): Yes, indeed there is a strong westerly wind toward W-MED a few days before the episode. {It may transfer ozone and its precursors from other places such as eastern US, etc. towards this region (via long-range transport), but there is not enough evidence for that through this maps.} However, on the 26th and 27th of April (in the lowest panel of the left column in Fig. 4), there is a weak wind flow over W-MED due to the existence of a high pressure system.

The back-trajectories in combination with the IASI satellite measurements show that the flow over W-MED originates from the high tropospheric ozone area over N. Atlantic. Of course, photochemical ozone production inside the anticyclone might also occur, which will be more emphasized in the paper.

17) Results and discussion, section 3.2, e): in those episode days, there is a positive temperature anomaly over W-MED due to high pressure system. It leads to even more ozone production through photochemical reactions, doesn't it?

Yes, of course. But the simultaneous appearance of positive and negative temperature anomalies is also a sign of tropospheric processes leading to subsidence occurring at the interface of both areas but shifted somewhat towards the negative temperature anomalies area, which is associated with colder and richer in ozone tropospheric air masses.

18) Results and discussion, section 3.2: "overall, over the same area of subsidence . . ."_how is it possible to have strong subsidence and strong wind together at the same time? Strong wind may even lead to a reduction of ozone by transferring them to the other regions.

This is actually a very good point, which might help clarifying the discussion. As mentioned also above, during high ozone episodes, we might have strong downward transport (or subsidence) and strong winds at the same time, which usually originate from high tropospheric ozone reservoirs (a frequently occurring situation observed at the eastern Mediterranean during summertime). This is, in fact one of the main points of this paper: during high springtime ozone episodes in the WMED comparable synoptic conditions and atmospheric processes occur as during high ozone in the EMED in summertime. On the contrary, lower ozone levels occur in the troposphere during autumn and winter seasons under similar conditions, as the tropospheric ozone levels are significantly lower. In addition, in EMED during summer strong westerly winds, transporting boundary layer air from the Atlantic, are usually associated with low ozone but the corresponding synoptic conditions are quite different if compared with the high ozone episodes associated with strong northerly descending winds over the Aegean Sea and the EMED (Kalabokas et al., 2013; Kalabokas et al., 2015).

19) Results and discussion, section 3.2: “In figure 5, the composite ozone IASI . . .”_ as the authors have already mentioned in this section, there is a signal of high ozone at free troposphere over C-MED and Atlantic. There is no explanation of how these are connected to high surface ozone over W-MED.

As also mentioned previously and according to observations, the connection might occur through advection, which follows the subsidence observed over the Atlantic. In fact, the CMED high ozone maximum observed by IASI is associated with processes occurring within the low-pressure system, leading to the enhancement of ozone levels. We agree that according to the meteorological analysis no influence is observed from the CMED tropospheric ozone maximum to the surface ozone observations in WMED.

20) Results and discussion, section 3.2, page 9, first paragraph: I think, adding Fig. 7 is just overemphasizing the same messages which have been already explained in Fig. 1, 2, and 3.

The figure will be removed following the reviewer’s suggestion and will be put in the Annex. The idea is just to show that similar synoptic patterns and associated processes occur also at 700hPa and 500 hPa levels, which indicate deep subsidence throughout the troposphere.

21) Results and discussion, section 3.2, page 9, second paragraph: the CHIMERE simulation shows more or less the same results as IASI satellite data. There is high ozone in the free troposphere over C-MED. I cannot understand how this information is connected to high surface ozone over W-MED? I do not recommend the authors to apply a model simulation in this study without any evaluation of that.

As mentioned previously, the analysis shows that surface ozone in W-MED is influenced from the high ozone reservoir over the Atlantic region (in addition to the photochemical production during the last days of the episode). On the contrary, we agree that the high tropospheric ozone over C-MED (related to the low pressure system to the east) does not influence the surface ozone concentrations in W-MED, as also mentioned above.

22) More or less the same recommendations as above are valid for section 3.3.

The May episode described in section 3.3 is quite different than the April episode regarding synoptic meteorological conditions, as the main anticyclone associated with the ozone episode is located in central and northern Europe and the corresponding discussion concerning the synoptic influence on ozone levels has been adopted accordingly.

23) Conclusions: “in this paper, the investigation of the regional . . .”_what does ‘surrounding countries’ mean? Does it mean C-EU?

The phrase means 'surrounding countries' of the northern and eastern part of the western Mediterranean basin, from which the results of the EMEP stations are presented in Fig. 1 (Spain, France, Switzerland, Italy, Malta).

24) Conclusions: paragraph 4: how do negative temperature anomaly and strong wind contribute to the high ozone level?

As mentioned also previously, strong winds might be associated with high ozone if they originate from a high ozone reservoir located in the upper tropospheric layers (as IASI measurements indicate). This rapid downward transport, transporting colder and richer in ozone air from upper layers located to the north, is associated in fact with a negative temperature anomaly, which usually appears next to a positive temperature anomaly area, located inside the anticyclone during subsidence conditions. These observations are in agreement and support the corresponding observations from the analysis of other meteorological parameters, indicating strong vertical tropospheric transport originating from northern directions.

25) I would strongly recommend the authors to use a larger size for labels, title, etc. for all figures to make them readable.

The new ECMWF Figs will take into account the above remarks.

Figure 1: The lower time series plot clearly shows the episodes. There is no need to keep both plots. Furthermore, the unit of ozone in the legend should be "ppb" instead of "ug/m3", shouldn't it?

The figure just shows that the high ozone concentrations occur also at Spain and Malta, especially for the April episode, which is important to show its extend over the western Mediterranean basin.
Yes, indeed, "ppb" should be used instead of "ug/m3", we apologize for this mistake.

Figure 2: The right column is specific humidity anomaly, but in the legend it is written specific humidity. It would be recommendable to add the unit of this parameter.

*In fact, "anomaly" should be added to "*specific humidity"*. Also, the unit of this parameter will be added in the legend.*

Figure 3: Both omega and omega anomaly have the same messages; I would recommend the authors to keep only one of them. Units are missing.

As mentioned also above, only omega will be retained in the main Figure list.

Figure 4: Again, adding units would be recommendable.

Units *will be added in the legend, according to reviewer's suggestion.*

Figure 9: It is hard to see the white contour over CHIMERE maps. In the legend the color of contours is labeled black instead of white. I do not know what the aim is of putting surface ozone (from EEA-AirBase) maps separately below CHIMERE simulation maps.

The white tracer contours of the CHIMERE maps will be replaced by black ones. Also the EEA-Airbase observations will be put together with the IASI measurements in the main Figure list (new Figs 3, 7).