

Interactive comment on “**Temporal and spatial analysis of ozone concentrations in Europe based on time scale decomposition and a multi-clustering approach**” by Eirini Boleti et al.

Anonymous Referee #2

The manuscript presented by Boleti et al. examines trends on surface ozone concentrations across a number of stations over Europe for the period 2000-2015. They use a time-scale decomposition to analyse long-term (LT), seasonal (S) and short-term (W) variations. Then, they apply a clustering technique and they finally calculate the trends in the clusters obtained. In addition, they analyse the ozone-temperature relationship over the different clusters and sub-periods. Their classification is consistent with previous studies and their results show a general decreasing in the ozone concentrations, mostly in the ozone peaks. In addition they find a reduced sensitivity in the ozone-temperature relationship over most of the clusters defined.

Overall, I found the manuscript very interesting and complete. The methodology applied is robust and consistent, as well as the results presented. However, I also think that there are some parts in the current version that should be improved in order to be published, in particular the methods sections (see my comments below). In my opinion the manuscript might be a good contribution to *Atmos. Chem. Phys* and the scientific community. Therefore, I would be happy to support the publication of the present manuscript after addressing some comments, which I consider that would be useful to improve it.

I have a few general comments and some specific comments:

General comments

There are some parts in the methods section that are not very clear, and in my opinion this section is essential to follow the manuscript. Therefore I have some comments and questions that I would like to ask the authors:

Section 3.1. Time scale decomposition (page5): The authors should explain in more detail the IMF. How the number of coefficients (c_j) is selected? The authors say “ By adding together IMFs with frequencies around 40 days and 3 years we obtain the seasonal variation of O₃ ($c_1+\dots c_{10}$)”, but why 40 days and 3 years? Is this based on the previous study from Boleti et al.2018? I think that this information should be included in order to help the reader to better understand the methodology.

Sections 3.3-3.4 Long-term trends (page 6, 7):

I understand that for the peaks of O₃ metrics the method explain in section 3.3 cannot be applied. But, it would possible to use the same method, i.e. GAMs models also for daily mean and MDA8 O₃, wouldn't it?

Why the authors define the warm season as May-September? Why April is not included? I think this should be further clarified, since usually ozone season ranges from April to September (e.g. EEA, 2019, Fleming et al. 2018)

Reading the modelling part (section 3.3, 3.4, page 6) is not clear the input data to calculate the trends, e.g. the GAM models are fitted to each cluster that contains a number of stations, so the models are applied individually to each station, am I right?

Regarding the analysis of seasonal cycle of O₃, why do the authors chose the mean of O₃ and not the MDA8O₃?

Specific comments

L26-30 of page 3. The authors applied a filter to obtain the time series, and only those with a maximum of 15% of missing values and maximum of 120 consecutive days are used. Is this 15% applied to whole period (16 years) or each year? And the consecutive days? I assume that they refer those 120 consecutive days in one year, is that correct? Can the authors clarify this?

L1 of page 5. I would add that the clusters are identified by using each component L(t), S(t), W(t) **separately** to the algorithm.

L4 of page 8. What are the temperature ranges considered?

L4 of page 9. Why do the authors leave the results of MDA8O₃ in the supplement and the results if the O₃ in the main text? Wouldn't it be more interesting to see the results for MDA8O₃?

L19-23 of page 9. Please refer to figure 3.

L25 of page9. Just a comment regarding Fig.4. the colours for “Po Valley” and “Central South” maybe could be changed, they are quite similar and it is hardly to distinguish the stations that belong to each cluster.

L4-L20 of page 10. Should Figure 5 be referred here? I couldn't find any reference to Fig.5.

L3 of page 11. “decreasing O₃ trends”, maybe it should be specified “decreasing daily O₃ means”.

L4 of page 11. In my opinion, the table 1 with the number of stations should be introduced before (e.g. when presenting the clusters).

L9 of page 14. Where these percentages 62% and 18% came from exactly? Is there any figure to support this? This question is in the line of one my previous comment (i.e. how the models are fitted).

L10 of page 19. In the North sites the variability of temperature is lower and O₃ is also more influenced by transport.

L24-26 of page 21. The authors attributed the decreasing O₃-Temperature to NO_x reductions, and this is likely one of reasons (but it is not showing here) and then, they mention that “changes in the sensitivity across sites are mainly driven by regional meteorological conditions”, so what about the NO_x emission reductions just mentioned? I think this last paragraph is important and it must be rewritten.

References

EEA: Air quality in Europe—2019. <https://www.eea.europa.eu/publications/air-quality-in-europe-2019>

Fleming, Z. L., Doherty, R. M., Schneidmesser, E. V., Malley, C. S., Cooper, O. R., Pinto, J. P., Colette, A., Xu, X., Simpson, D., Schultz, M. G., Lefohn, A. S., Hamad, S., Moolla, R., and Solberg, S.: Tropospheric Ozone Assessment Report : Present-day ozone distribution and trends relevant to human health, *Elementa: Science of the Anthropocene*, 6, doi:<https://doi.org/10.1525/elementa.273>, 2018.