

## ***Interactive comment on “Retrieval and evaluation of tropospheric aerosol extinction profiles using MAX-DOAS measurements over Athens, Greece” by Myrto Gratsea et al.***

### **Anonymous Referee #1**

Received and published: 26 May 2020

The paper by Gratsea et al. reports on MAX-DOAS measurements of aerosols at Athens, Greece. The MAX-DOAS were utilized to retrieve aerosol optical depths and vertical profiles of the aerosol extinction applying the BOREAS retrieval algorithm developed by the University of Bremen. The paper describes the potential and the application of a remote sensing technique to retrieve aerosol properties. Thus, the paper is relevant for the Atmospheric Measurement Techniques Journal. Although the study is based on a limited number of selected cases, provides a representative dataset for different atmospheric conditions of the under-study area. For the evaluation of the extinction coefficient retrievals, the aerosol extinction was compared with Lidar measurements and the aerosol optical depth with sky radiometer measurements, both in-

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struments within a distance of 15km from the MAX-DOAS. Although the paper misses a comprehensive dataset, the 4 selected cases were modeled and compared with the measurement, showing promising results. The paper is well organized, and clear. I recommend the publication in AMT after revisions outlined in the following sections:

#### General comments

In order to avoid confusions, the same time zone should be used in the figures and throughout the manuscript. Please avoid the use of both LT and UTC. As the instruments used in the study are part of EU and International Infrastructure networks the use of the UTC is preferable.

The same unit format should be kept in the manuscript (e.g. m/s or ms<sup>-1</sup>).

It is very difficult for the reader to follow the discussion and the Figures when only the case numbering is given. The discussion of the cases as well as the headers of the Figures should be based on the dates of each case or at least the dates and hours of the data should be given together with the case numbering in the plots.

#### Specific comments

##### Introduction

The authors nicely present the advantages of MAX-DOAS compared to established aerosol measurement techniques (e.g., simple and low cost instrumentation, the ability to perform long-term measurements also in remote areas, the ability to retrieve information on the vertical distribution of aerosol in contrast to sun photometers which only yield AOD) but the shortcomings and the limitations of the technique should also be mentioned in more detail in the introduction.

##### Section 2.2.2

One of the major points of the evaluation of the MAX-DOAS aerosol extinction retrievals is the comparison with the extinction lidar profiles. As the study makes use of daytime

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lidar measurements an assumption of the lidar ratio is needed for the retrieval of the lidar extinction profile. In the manuscript the authors mentioned that the same lidar ratio is used for all cases. Did the authors check the lidar retrievals with e.g. comparison with AOD columnar observation from Cimel?

The uncertainty of the extinction lidar profiles should be discussed, estimated, and given in the manuscript.

In the L:177-178 the authors stand that the height independent extinction coefficient is representative for the aerosol load in the overlap region, is there any reference that supports this statement? The 1km of the overlap height range is still within the Planetary Boundary layer where an assumption like this could be accepted?

### Section 2.3

Although already published elsewhere, the general approach and the main features of the algorithm and the optimal estimation method need to be described. For example, a definition of the box air mass factor is missing. What is the a priori aerosol Number concentration profile that is used for the BOREAS retrievals?

The authors should provide further information related to the extinction profiles uncertainties and possible biases in the evaluation with lidar and sun-photometer retrievals due to the a priori selected values.

Table 2 provides information for the input parameters of the 4 selected cases, before the description of the selected cases in the manuscript. Table 2 could provide more generic information, or a rearrangement of the text is needed.

### Section 3.1

A Table providing information (e.g date, atmospheric conditions, air masses), for the 4 selected cases may help the reader to have a better view of the differences and the similarities between the cases. Also, a table will facilitate the reader to follow the discussion which is referring in cases numbering and not in the dates of the cases.

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L226: what kind of in situ meteorological observations provide information for cloud free conditions?

Figure 1: A closer map of the area with terrain could better highlight the special topography of the under-study region as well as the orientation and the elevation difference between the instruments. What is the green area in the Figure 1?

### Section 3.2

Since the authors present a technique with main scope to deliver reliable results sensitivity studies are necessary. There is no information how much of the uncertainty of the retrieval is derived from the measurements and how much is from the a priori input. Furthermore, error bars in Figure 6 would help the reader to evaluate the retrieval.

Since AERONET measurement are used based on their availability either for the specific date or as a climatological mean value, the resulting uncertainty on the extinction profile should be further discussed and estimated.

### Section 3.3

L275: Is the average of more than one extinction profiles, or the average of the lidar signal for the same time window as the MAX-DOAS retrievals? Please be specific.

L276: Please provide numerical estimation of the uncertainty in the extinction retrievals.

The authors should avoid general and non-specific comments, e.g L292: some discrepancies, L296: some performance statistics. Please rephrase.

L339: an aerosol layer of about 1.5 km deep. In which height?

### Section 3.4

AOD calculations from Lidar

In which height range the lidar AOD have been calculated? It is limited to the first 4

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km? is there any aerosol layer above 4km that may contribute to the AOD?

AOD evaluation with AERONET

It is possible the underestimation of the MAX-DOAS to be related to the fact that the AOD from sun photometer is referring to the total column of the atmosphere and the MAX-DOAS covers only the first 4km. Did authors examine the presence of aerosol layers above 4km (e.g lidar observations) for the selected cases? Is this the case for any of the 4 under study cases?

Additionally, the 370m height difference between the location of sunphotometer and MAX-DOAS could have contribution to the AOD differences. This point should further discussed in the manuscript.

Based on the altitude differences and keeping in mind the limitations of lidar to retrieve trustworthy extinction below the full overlap region and the fact that the MAX-DOAS provide profile up to 4km, a comparison of the AOD for the atmospheric layer between 1-4km could provide better conclusions. Is there a reason why this has not been done? The authors should consider to repeat the evaluation of the MAX-DOAS for different altitude ranges.

Section 4

There is a repetition in 2nd (L:455-463) and 5th (L485-490) paragraph. Please improve the text.

Line466: The authors should be more specific under which atmospheric conditions there is a better agreement. Statements like "in most cases" should be avoid. Please rephrase.

Technical corrections

Figure 1: Possible a map with terrain could better highlight the unique topography of the under-study region as well as the orientation and the elevation difference between

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the instruments. What is the green area in the Figure 1?

Figure2: Case numbering should be added in the plots.

Figure 3: The Dates (and hours) should be given as a header in each plot together with the case (i-iv).

Figure 4: The case (i-iv) should be also given in the plots to facilitate the reader to follow. Please also provide the spatial and temporal analysis of the retrievals in the caption.

Figure 5: The Dates (and hours) should be given as a header in each plot together with the case (i-iv).

Figure 6: The Dates (and hours) should be given as a header in each plot.

Figure 7: The same axis (horizontal and vertical) should be used for each case. Please use the same x-axis (04-17 UTC) for all plots. Maybe a y-axis set at AOD=1.0 will make the plots less busy. Please keep the same format for each plot. The legend of top left plot seems incorrect (e.g lidar 520nm.) Please also mention the date for each case.

Table 2: Please correct ... "Next year's monthly mean".

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