

Answer to Reviewer #2

The authors greatly acknowledge the anonymous reviewer for carefully reading the manuscript and providing constructive comments. In the following lines we answer the questions and comments from reviewer #2.

1.- The scientifically most important result of this work seems to me that no statistically significant difference in aerosol optical properties at night or day was found when one might expect some due to diurnal variations in atmospheric dynamics or anthropogenic aerosol sources. Perhaps such differences are washed out by statistical averaging over several years. I would therefore suggest adding a section dealing with e.g. case studies for single days in different seasons or an analysis of weekly patterns in day versus night time observations.

As we have discussed and evidenced in the old version of the manuscript, in general, there were no significant differences in aerosol optical depths, $AOD(\lambda)$, and Angström exponent, α , obtained both at day and night. However, differences in fine radius mode, r_f , and fine mode contribution to AOD, η , between day and night were found out, as was evidenced by the analysis of Gobbi type diagrams. These differences were associated with diurnal variations in atmospheric dynamics and aerosol sources as well as meteorological conditions. However, we agree with the reviewer that the statistical averaging of data over several years may wash out the possible differences in aerosol optical properties between day and night. In this sense and following the reviewer's suggestion, we will add in the new version of the manuscript a section dealing with two different case studies; the first one correspond to the period 18 June to 2 July 2008 focusing in summer conditions, while the second one goes from 21 January to 2 February 2008 being representative of winter time. In this new section we will present an in depth analysis of day and night-time columnar $AOD(\lambda)$ and Angström exponent variations. Moreover, to make clear the differences between consecutive days and nights in the fine mode radius and fine mode contribution to AOD we will analyse Gobbi type diagrams for these case studies.

For both cases, continuity in AOD and α are observed between day- and night-time (see Figures 1 and 2 below). Moreover, the AOD and α show large day-to-day and night-to-night variations which are explained by the changes in the origin of the air-masses that affected the study area during these periods. Nevertheless, analysing only the AOD and α parameters it is difficult (as in the seasonal analysis of these parameters) to obtain clear information about the aerosol dynamic and the changes in the aerosol characteristics between day and night for the case studies shown in Figure 1 and 2. Thus, to make clear the differences in the aerosol characteristics between consecutive days and nights, we also analyse Gobbi type diagrams for these case studies. For the summer case, Figure 3 shows Gobbi diagrams for every day and night of this period. It can be observed the increase in r_f and η at night-time for each air-mass type. These findings agree with those obtained in summer season shown in Figure 8 in the original manuscript. As commented in the old version of manuscript, the dryness of the terrain and the intense convective activity processes during summer at day-time can explain the larger contribution of coarse particles (and thus lower η) at day-time. Furthermore, the evident increase

in r_f at night-time can be explained by aerosol aging processes. For the winter case, only a few days and nights fulfil the requirement ($AOD(670\text{ nm}) > 0.15$) imposed in Gobbi et al., (2007). In this sense, Figure 4 shows these diagrams only for the limited period between 26 and 28 January 2008. From this last figure, it can be observed that r_f and η values at day-time are larger than those obtained at night-time, indicating large contribution of fine mode particle and an increase in fine mode radius during day time in winter. These differences are explained by the differences in the aerosol sources between day and night-time during the winter season as stated in the current manuscript. More detailed discussion of these results is included in the new manuscript version

2.- While night-time observations may be valuable for studying aerosol processes on short time scales, their long-time climatological mean is rather unimportant in the context of radiative forcing unless additional aerosol properties, single scattering albedo resp. emissivity, in the thermal radiation wavelength domain are considered. What is the scientific value of night-time observations that are bracketed by accurate day-time measurements?

We agree with referee that the night-time aerosol properties presented in this study are rather unimportant in the context of aerosol radiative forcing and that additional aerosol parameters are needed in order to evaluate the long wave aerosol radiative forcing. However, the knowledge of night-time columnar aerosol properties is quite important for better understanding of aerosol dynamics. Also, night-time measurements can allow us to have a whole picture of the daily behavior of the atmospheric aerosol, covering the different stages in the evolution of the planetary boundary layer and pre-convection and pre-photochemistry processes that affect the atmospheric aerosol. In addition, the knowledge of columnar aerosol properties at night-time would contribute to aerosol transport and chemistry models validation efforts, and thus research studies focusing on columnar aerosol properties at night-time are calling for to better understand the aerosol role in air-quality as well as aerosol long-range aerosol transport. Moreover, columnar aerosol properties measurements at night-time can be also used as constraints for correlative ground and space elastic lidar measurements, which can help to reduce the uncertainties in aerosol properties derived from elastic lidar measurements. For these reasons, currently some research groups are working with irradiance measurements from stars (e.g. Herber et al., 2002; Perez-Ramirez et al., 2008; Baibakov et al., 2009) or from the moon (e.g. Exposito et al., 1998; Herber et al., 2002; Berkoff et al., 2011) to obtain aerosol optical properties at night-time. In order to clarify and highlight the scientific importance of night-time measurements of columnar aerosol properties this information will be clearly discussed in the revised manuscript.

3.- The authors claim their work to be the first analysis of day-and night-time observations although they cite the work of Herber et al., who already did some pioneering work in Polar night observations ten years ago. Maybe they should emphasize that the novelty of their work lies in the continuity of

observations over day-night-day cycles. This then naturally lead to a motivation to study this cycle on timescales shorter than years.

We agree with the reviewer that our work is not the first one that deals with the analysis of night-time columnar aerosol optical properties observations. First attempts in star-photometry were made by Leiterer et al., (1995) who installed an instrument based on photo-detector as detector device, acquiring very valuable measurements during 10 days in April 1994 at Lindenberg observatory (52.14°N; 14.12°E; Germany). Moreover, this instrument design was used by Herber et al., (2002) to acquire measurements during the Artic winter from 1996 to 1999 at Koldeway station in Ny-Alesund (78.95°N; 11.93°E; Norway). However, due to the characteristics of this site, this last study did not acquire measurements between consecutive days and nights, and thus no comparison between day- and night-time AOD and α were possible. Thus, the novelty of our work lies in the study of columnar aerosol properties both at day and night which have not been done in previous studies. Particularly we study a long data base of 4 years of day and night measurements, giving special attention to the Angstrom exponent and its spectral variation to evaluate differences in columnar particle sizes (types) between day and night. Therefore, according to the reviewer's suggestion we have emphasized and clarified in the new version of the manuscript these aspects. On other hand and we have added a new section where we have analysed and discussed carefully night and day columnar aerosol properties variation in short time scales (see our response above).

4.- Although the comparison with surrounding AERONET stations might be useful in relating day-time AOD results at Granada with a wider context, it only slightly improves the value of this paper with respect to ACP focus on studies with general implications for atmospheric science rather than investigations that are primarily of local or technical interest. This concern is supported by the authors in their conclusions (L533) cautioning that their findings are only applicable to a particular site and particular period. I think that the scientific potential of their data set is not adequately exploited by the paper as it is now and suggest a major revision.

As we have commented in the old version of the manuscript, the observed changes in columnar aerosol optical properties between day and night were associated with the diurnal variations in the local atmospheric dynamics and aerosol sources as well as local meteorological conditions. In this sense, we think that our findings can only extrapolated to sites with similar characteristics to our site study. Considering the referee criticism we will clarify and emphasize this point in the new manuscript version.

Concerning the adequate exploitation of data set, we want to mention that we will add in the new version of the manuscript a new section where we will analyse and discuss the aerosol properties for two case studies in more details: one during the winter and the other during the summer season (see our response above).

References

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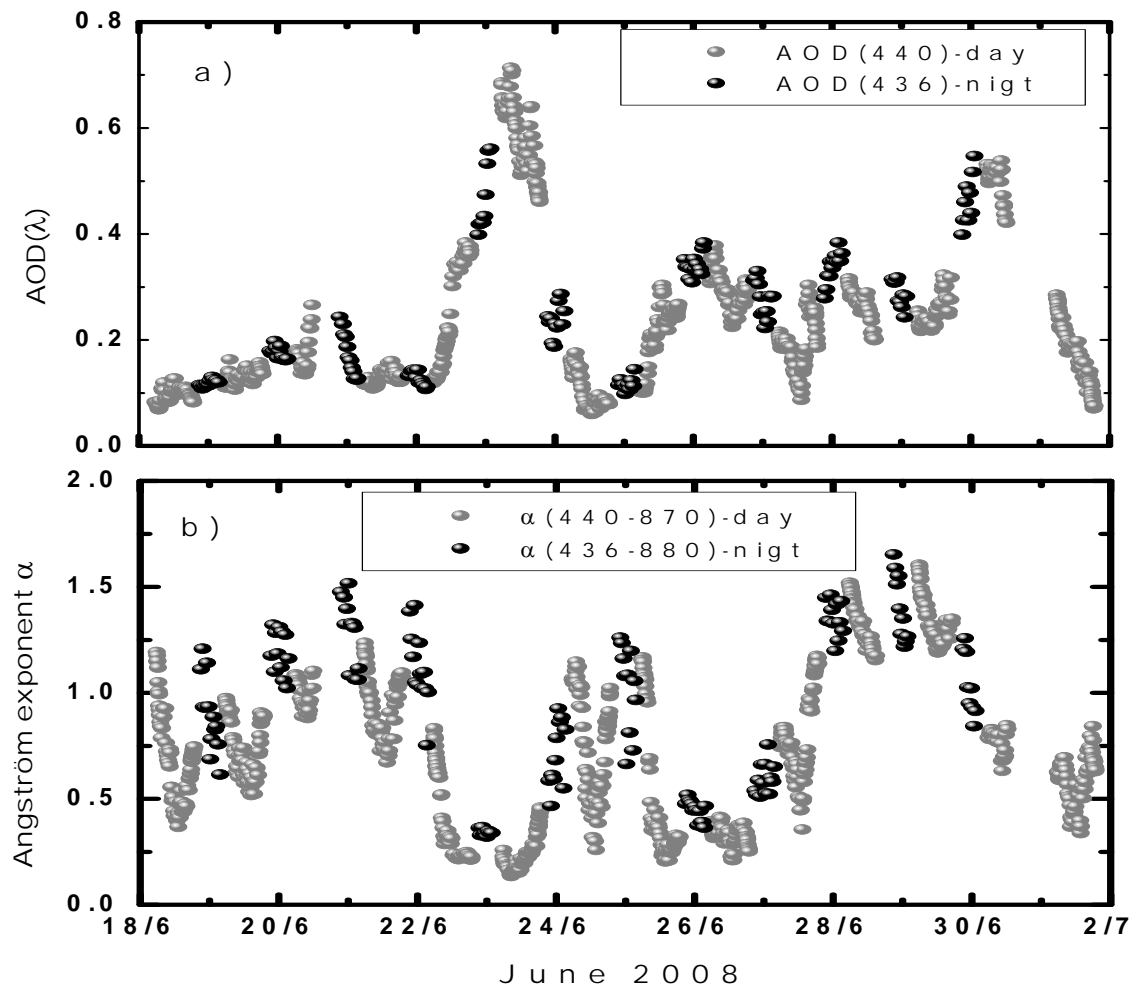


Figure 1: Day- and night-time evolutions of columnar aerosol properties for the period from 18 June to 2 July 2008. a) Aerosol optical depth (AOD) and Angström exponent α

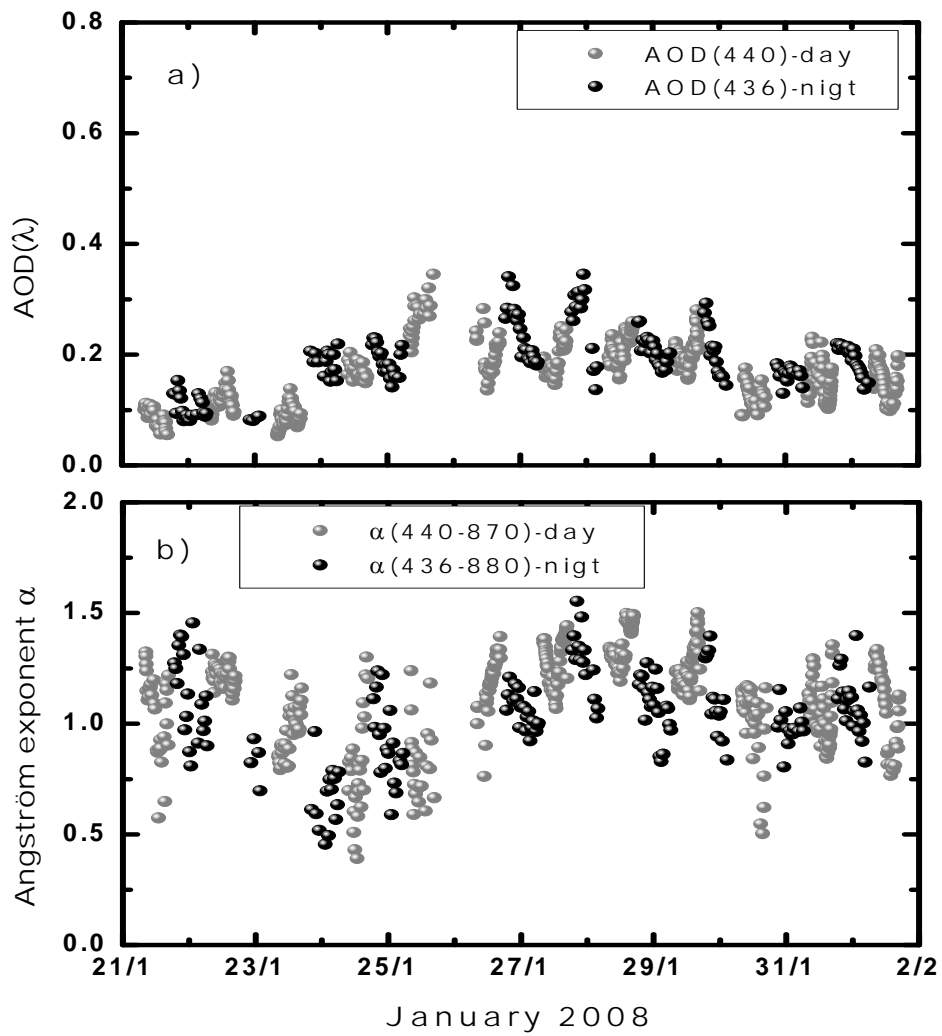


Figure 2: Day- and night-time evolutions of columnar aerosol properties for the period from 21 January to 2 February 2008. a) Aerosol optical depth (AOD) and Angström exponent α .

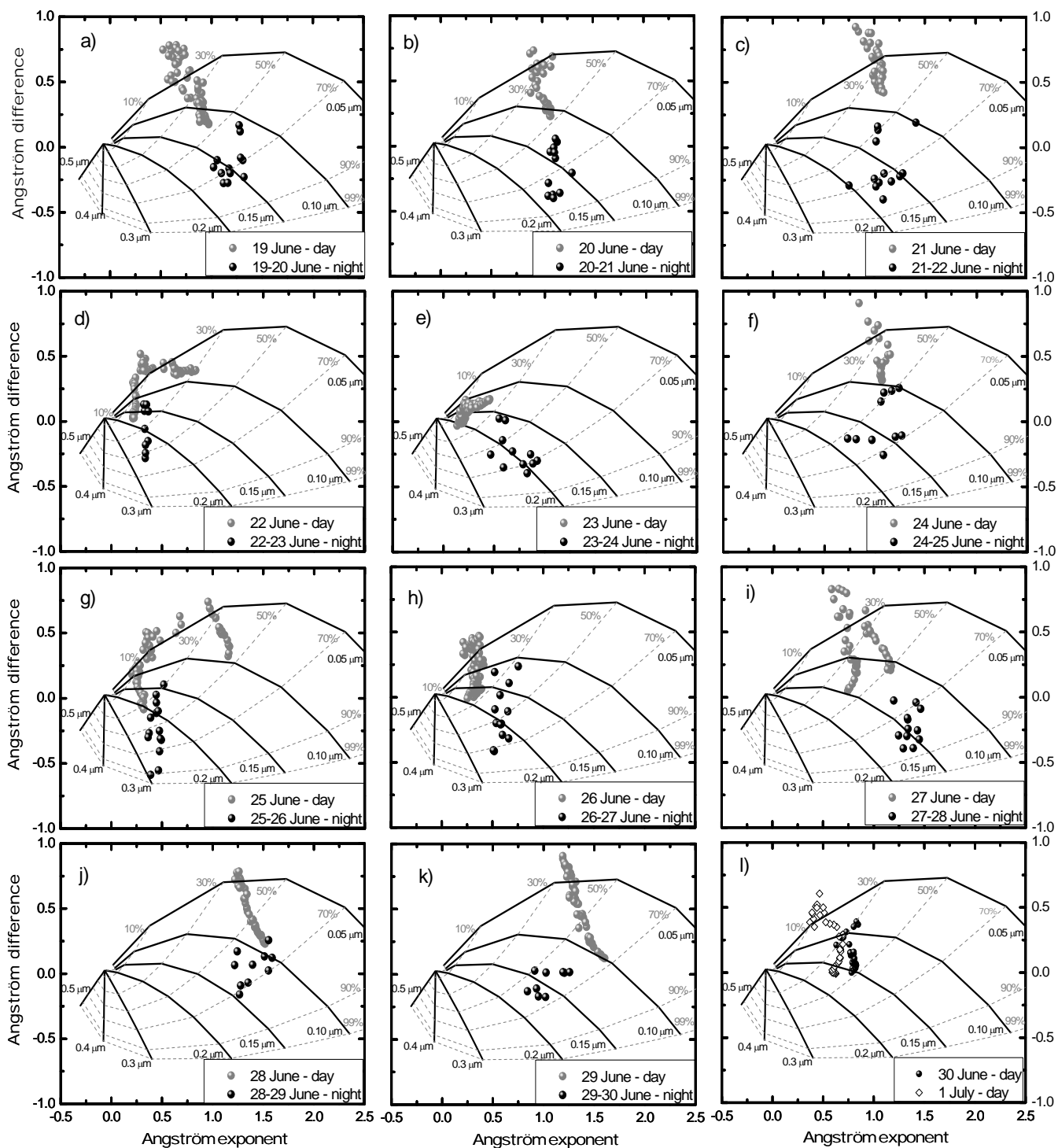


Figure 3: Angström exponent difference $\delta\alpha = \alpha(440-670 \text{ nm}) - \alpha(670-870 \text{ nm})$ as function of $\alpha(440-870 \text{ nm})$ at day and $\delta\alpha = \alpha(436-670 \text{ nm}) - \alpha(670-880 \text{ nm})$ as function of $\alpha(436-880 \text{ nm})$ at night-time, for summer case study. The data corresponds to the period from 18 June to 1 July 2008,

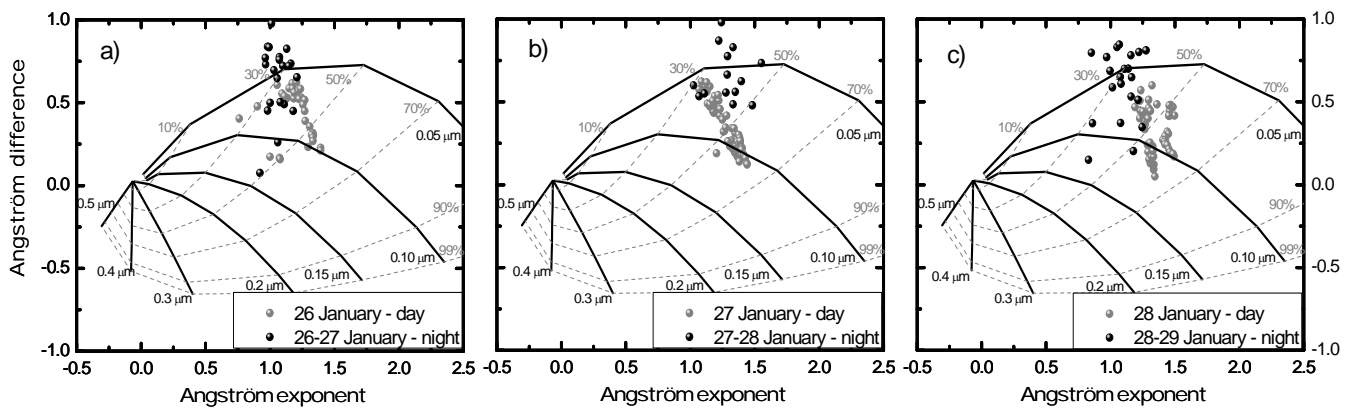


Figure 4: Angström exponent difference $\delta\alpha = \alpha(440-670 \text{ nm}) - \alpha(670-870 \text{ nm})$ as function of $\alpha(440-870 \text{ nm})$ at day and $\delta\alpha = \alpha(436-670 \text{ nm}) - \alpha(670-880 \text{ nm})$ as function of $\alpha(436-880 \text{ nm})$ at night-time, for winter case study. The data corresponds to the period from 26 to 29 January 2008.