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Atmospheric Measurement Techniques Discussions

Interactive comment on "Measurement of aerosol optical depth and sub-visual cloud detection using the optical depth sensor (ODS)" *by* D. Toledo et al.

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Referee comment 1: Page 9619, lines 14-15. Additional comments about the comparison between the 3D Monte-Carlo model and SHDOM model are needed, include a reference about that if it exists.

Author's response: This is a reasonable suggestion. We have changed the lines 15-18 in page 9620 by: "For testing the reliability of calculations, first the radiance simulated by SHDOM code was compared against the DISORT plane-parallel radiative transfer code and using different values of the number of streams. These comparisons were carried out for a total opacity of 0.5, a single scattering albedo of 0.8 and different phase functions. In order to check the plane-parallel approximation, these simulations

were carried out for SZA=0°. We obtained same results using both codes and the simulations demonstrated the need of using at least 16 streams in the calculations. Subsequently, SHDOM calculations were compared against a tested Monte-Carlo radiative transfer code in spherical geometry (Trân, 2005) for SZA between 0° and 90°. The results were showing the reliability of SHDOM simulations at SZA between 0° and 80° (Toledo, 2015)."

This reference has been added in the manuscript: Toledo, D.: Preparation and validation of the cloud and dust opacity sensor ODS for ExoMars 2018 mission. PhD thesis in Astrophysics, Univ. Reims Champagne-Ardenne, 2015.

Referee comment 2: Pages 9623-9624 Move AERONET description, first paragraph of section 4, to the end of section 2

Author's response: Done.

Referee comment 3: Page 9624, around line 25 It seems like there are two regions with different be- haviour in figure 14b: A linear region close to the straight line 1:1 for AODs below 0.8, and a second region above 0.8 where the linear behavior is more separated from the 1:1 line. Could you go deeper in the analysis of the meteorological situations corresponding to the points with an AOD above 0.8?

Author's response: The principal reason of such behaviour is the strong variability of AOD during Saharan dust storms. While the daily average AERONET AOD is calculated taking the instantaneous measurements of AOD during the day, ODS AOD is retrieved by using observations acquired during the whole day. Therefore, for days with high variability of AOD during the day, ODS and AERONET daily average measurements can differ due to this reason. In order to deal with these discrepancies, we estimated two values of AOD from ODS measurements for days with a daily average AOD above 0.8. This is to say, one AOD value is estimated using only half of ODS signal (roughly from 7:30 to 12:00) and the second value from the observations acquired the rest of the day (roughly from 12:00 to 16:30). Figure 1a shows the evolution of ODS blue signal measured on 05 January 2005 and those simulated for the AOD values retrieved using ODS observations acquired between 7:30 and 11:50 UTC (AOD=1.57), and between 11:50 and 16:30 UTC (AOD=1.34). A similar analysis as shown in Figure 14b was carried out but in this case two AOD values were estimated for the days with a daily average AOD above 0.8 (Figure 1b). The correlation between AERONET and ODS improves to 0.97 and the MBE and MABE parameters to (-13.82±0.9) and (15.01±0.7). Therefore, these results point out the need of retrieving two values of AOD for days with a high variability of this parameter.

Figure 1 has been added in the manuscript as well as the following text in page 9626 (line 6): "We observe also in Fig. 14 a larger underestimation of ODS measurements in respect to AERONET for AOD values larger than 0.8. The main reason of this is the strong AOD variability during dust storms. While the daily average AERONET AOD is the mean of instantaneous measurements of during the day, the ODS AOD corresponds to ODS observations acquired during the whole day. For days of high AOD variability, ODS and AERONET might be thus very different. To deal with these differences between instruments, two half day AOD ODS values have been retrieved for days of AOD larger than 0.8,respectively in the morning from 7:30 to 12:00 UTC and the afternoon from 12:00 to 16:30 UTC. Fig. 15a shows, an example of the ODS blue signal evolution on 5 January 2005 and those simulated for the two AOD values retrieved using half day only signal. A similar analysis as shown in Figure 14 was performed for this case of two AOD values larger than 0.8. The correlation between AERONET and ODS is shown in Fig. 15b where the R2 coefficient improves to 0.97 and the MBE and MABE parameters to -13.82±0.9 and 15.01±0.7,respectively. Despite the AOD underestimation the results are showing that ODS measurements are reliable over a large range of AOD."

In addition, lines 13-17 in page 9628 (conclusions section) have been changed as follows: “The AOD in Ouagadougou is found highly variable ranging between 0.1-1.7 displaying strong maxima during Saharan dust storms. Under such conditions, we

found necessary to retrieve two AOD values per day for days of AOD larger than 0.8.”

Referee comment 4: Page 9627, line 7-9. When speaking about night time retrievals. Could you explicit the reasons of departures between CIMEL AOD and ODS night AOD. For example, there is a big step in the data around the day 331 of figure 16. AOD from ODS is increased from 0.8 up to 1.4 but there is no increment in the CIMEL AOD.

Author’s response: The analysis of these big steps in aerosol load is complicated due to the big error bars of ODS measurements. Note that ODS error bars for those cases are big largely due to the few ODS observations used for the estimations of AOD. While during daytime the daily average AOD is estimated for a time interval of around 9 hours, during nighttime the AOD is estimated for time intervals of around 3-4 hours (depending on the night). The time period from the last AERONET measurement and the first ODS measurement during night time for the estimation of AOD, as well as from the first AERONET measurement and the last ODS measurement during night time is between 4-7 hours. Therefore, during such nighttime periods the aerosol load can increase notably and subsequently decrease. In such cases, the last AERONET measurement and the first one of the next day would provide low values of AOD respect to ODS measurements. We have found several of such cases during day-time, some of them are illustrated in Figure 2 where we can observe big steps in the aerosol load for short periods of time. The point here is to establish if the increases observed by ODS during night-time correspond to cases similar to those illustrated in Figure 2. In this regard, it is essential to compare ODS retrievals during nighttime against lidar measurements in order to explain those differences between AERONET and ODS as well as to compare ODS retrievals.

Referee comment 5: Page 9628, lines 16-19 The sentence "Results also demonstrate the capability of ODS to retrieve the AOD during the night when moon crosses the FOV of ODS, allowing the investigation of AOD for the whole day. However, we remark here the need to compare these measurements with a lidar to further analyze the reliability and robustness of the retrieval procedure during night-time.". At least 25% of the night time AOD points shown in figure 16 present big differences with CIMEL AOD evolution. I think that it is require more work than just a comparison with a LIDAR as the authors say.

Author's response: Following this reviewer comment as well as the previous one we have included in page 9627 (line 6) of the manuscript the following text: "...strong AOD increases are observed on some days at night followed by a decrease in the morning. Since nighttime AERONET and ODS measurements are separated by about 4-7 hours, it is clear that the aerosol load can change strongly from one measurement to the other. Strong changes in AERONET aerosol load were frequently observed within 3-6 hours, consistent with the differences between ODS and AERONET data. A better understanding of AOD change might be provided by simultaneous ODS and lidar measurements."

In addition we have changed the sentence indicated by the reviewer (page 9628, lines 19-21) as follows: "The results also demonstrate the capability of ODS for AOD retrieval during the night when the moon crosses the ODS FOV, allowing the AOD investigation during the whole day. However, about 30% of ODS nighttime measurements are showing large differences with AERONET at 07:00 and 16:00 UTC, differences which might indicate a nighttime AOD variations related to wind velocity changes. However such study requires additional measurements, such as lidar and winds to validate the ODS nighttime retrieval procedure and to explore the potential AOD diurnal changes."

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 9611, 2015.

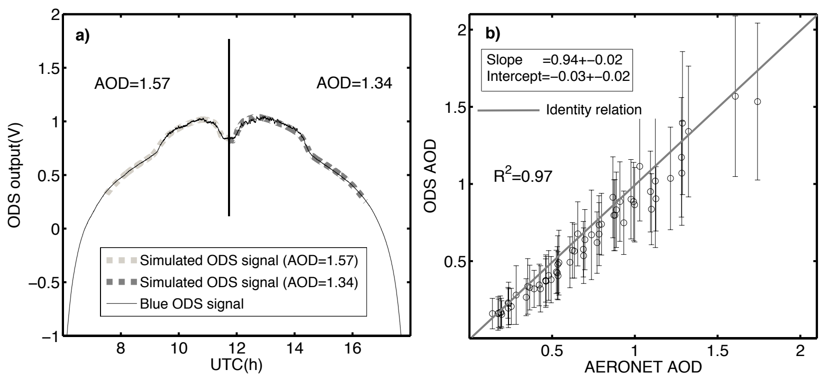

Fig. 1. Figure 1. (a) Evolution of ODS signal measured on 5 January 2005 and those simulated for the AOD values obtained by the retrieval procedure of dust opacity using only half of the day. (b) Correlation

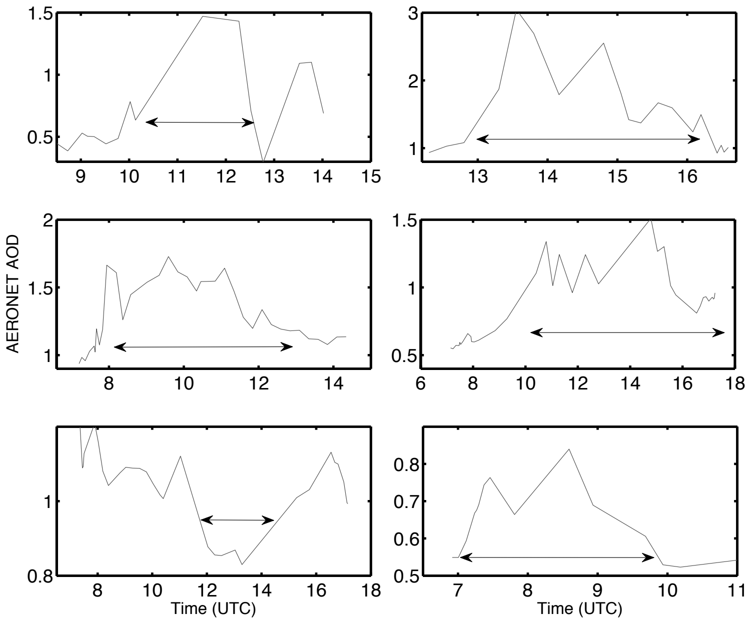

Fig. 2. Figure 2. AERONET measurements in Ouagadougou on 13, 17 December 2004, 26 February 2005 and 11, 13, 31 March 2005.