Response to the Referee #1 comments for the manuscript "Correction of a lunar irradiance model for aerosol optical depth retrieval and comparison with star photometer" By Roberto Román et al. in AMTD

First, we are grateful for the effort of Referee #1 and her/his review in detail. Reviewer comments are in black font (RC), and author comments (AC) in red font.

Author's answer to Anonymous Referee #1

RC: In this paper, a method for estimating RIMO correction factor (RCF) was developed for correcting the low bias in lunar irradiance as computed from the RIMO model. The RCF was developed by comparing reference aerosol optical depth (AOD) values estimated using daytime observations over pristine conditions with AODs estimated from Gain calibration. The retrieved nighttime AODs from moon photometer, with the use of RIMO RCF, are inter-compered with AODs from star photometer measurements. This paper presents a study that shall be interesting to users who use RIMO for nighttime aerosol and cloud property retrievals. Still, there are some minor issues that I would like the authors to make changes.

Line 39-41, "Finally, the direct effect of aerosols on solar radiation at night-time is avoided, but the aerosols presented at night-time can profoundly modify the longwave balance by means of the change in cloud properties and the impact on the longwave radiation absorbed by clouds, which is back-emitted to the Earth's surface". Add references to justify the comment.

AC: The sentence has been modified in order to be clearer and some references have been added. The new sentence is:

"*Moreover, the aerosols at night-time can profoundly modify the longwave balance by means of the change in cloud properties, such as cloud lifetime, and the impact on the longwave radiation absorbed by clouds which is back-emitted to the Earth's Surface (Ramanathan et al., 1989; Boucher et al., 2013).*"

References:

Ramanathan, V., Cess, R. D., Harrison, E. F., Minnis, P., Barkstrom, B. R., Ahmad, E., and Hartmann, D.: Cloud-Radiative Forcing andClimate: Results from the Earth Radiation Budget Experiment, Science, 243, 57–63, https://doi.org/10.1126/science.243.4887.57, 1989.

Boucher, O., Randall, D., Artaxo, P., Bretherton, C., Feingold, G., Forster, P., Kerminen, V.-M., Kondo, Y., Liao, H., Lohmann, U., et al.:Clouds and aerosols, in: Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Reportof the Intergovernmental Panel on Climate Change, pp. 571–657, Cambridge University Press, 2013.

RC: Line 121, “Sky at solar aureole and Moon measurements are recorded by the same detectors than Sun but with an amplification” This sentence is confusing and may need to be rewritten. What is “same detectors than Sun”?

AC: The photometer takes measurements of solar irradiance (Sun measurements) at daytime. This Sun measurements are taken with two detectors (one Silicon detector one InGaAs detector for the short wave infrared wavelengths), but without any amplification. Both detectors are also used for the sky and Moon measurements, but due to the lower signal in these cases, electronic amplification is used to increase the signal to noise ratio. The gain factor is 128 for aureole (sky) measurements and 4096 for direct Moon observations. We have rewritten the sentence as follows:

“*Sky radiance at solar aureole and direct Moon irradiance are measured with the same detectors used to measure direct solar irradiance, but with an electronic amplification factor (gain) of 128 and 4096, respectively.*”

RC: Line 123, “are recorded with the same gain than Moon observations”. I believe “than” should be “as”?

AC: This sentence has been modified (see previous comment) and the word “than” has been removed.

RC: Lines 135-136, “AOD in these spectral bands will be assumed equal to the AOD at 440, 500, 675 and 870 nm in order to compare with the CE318-T photometer” Why not interpolate star photometer data to the precise wavelengths as used by the moon photometer. If the authors do not want to match wavelengths from the two instruments, they need to document uncertainties introduced by the differences in wavelengths between the two instruments.

AC: The wavelength differences between both instruments are small, being 4, 5 and 10 nm for 440 nm (436 nm for star ph.), 675 nm (670 nm for star ph.) and 870 nm (880 nm for star ph.) nm. To study the influence of this assumption, the AOD values from Moon photometer have been interpolated to the star photometer wavelengths following the Angström law (using the two neighbour wavelengths). The changes on the obtained results (Table 2) are not significant when this interpolation is applied.

Moreover, the mean values of the AOD differences with and without interpolation for the analysed data have been -0.0013, -0.0007 and 0.0006 for AOD_{440}-AOD_{436}, AOD_{675}-AOD_{670} and AOD_{870}-AOD_{880}, respectively. These differences are one order of magnitude below the daytime AOD uncertainty.

Hence, we decided not to interpolate AOD to match the wavelengths, because it does not affect significantly the obtained results. The wavelengths are really close and we prefer to use the measured AOD by each instrument in order to avoid any kind of possible artefact caused by the wavelength interpolations.

In the text it is mentioned now:

“*AOD in these spectral bands will be compared to the AOD at 440, 500, 675 and 870 nm of the CE318-T photometer; the central wavelengths of these bands are close enough (below 10 nm difference) to allow a direct comparison of measured AOD and avoid interpolated data. If AOD of the CE318-T is interpolated to match the star photometer bands, the comparison does not significantly change (in general AOD differences below 0.001).*”

RC: Lines 164-165, "This fact makes that the knowledge of the absolute extraterrestrial irradiance is not needed in the AOD calculation" This sentence is confusing. Please rewrite

AC: It has been rewritten as:

"*A main advantage of Sun photometry is that the measured irradiance is directly emitted by the Sun and then, the solar irradiance reaching the top of atmosphere (extraterrestrial irradiance) does not significantly change, at least along one day. The Earth-Sun distance is the main factor modulating this irradiance, causing variations about ±3% along the year. Following the Beer-Bouguer-Lambert law, the extraterrestrial signal of the instrument (rather than irradiance in physical units) is needed for AOD calculation. This can be obtained by the Langley plot method (Shaw, 1976, 1983), in which direct Sun irradiance is observed at different solar elevations in order to extrapolate the top-of-the-atmosphere signal of the instrument. Side by side comparison with a reference instrument is the common practice in AERONET for calibration transfer in field instruments (Holben et al., 1998; Toledano et al., 2018; Giles et al., 2019; González et al., 2020).*"

RC: Line 213, please explain the "Langley-plot method" using a few sentences. Not all readers know about the concept.

AC: See comment above.

RC: Lines 248-249, "Moreover, some cloud contaminated nights have been discarded manually by visual inspection in order to warranty the AOD quality." What are the criteria for the mentioned visual inspection? Home many data points are excluded by this step?

AC: This step rejected 37 nights. This information is included in the revised manuscript:

"*Moreover, a total of 37 cloud contaminated nights have been manually discarded by visual inspection (nights without a smooth AOD time series) in order to warranty the AOD quality*"

The rejection of these nights is important, since the pristine conditions can be achieved at the previous afternoon and the next morning but clouds can appear during the night, producing non useful data. The best way to detect cloud contaminated data is by data visualization (AOD spikes, etc., see plots below). A standard cloud-screening may not properly work because uncorrected RIMO values produce unrealistic AOD: negative values, strong dependence on moon zenith angle, reverse wavelength dependence, etc. Such non-physical AOD would be rejected by any screening algorithm, even in clear nights.

When a night is selected as pristine (it previously satisfied the established Langley criteria in the previous afternoon and the next morning) and cloud-free, the behaviour of AOD is the shown in the example of Figure R1 for 500 nm. The AOD at night-time does not present good values (dependence on MZA and negative AOD) since the RCF is not applied, but its time series is smooth, which indicates no cloud presence. However, Figure R2 shows a case satisfying the pristine conditions before and after the night but with cloud presence during the night, which is appreciated in the data jumps and the non smooth AOD time series. The case of Figure R2 is one of the 37 rejected nights.

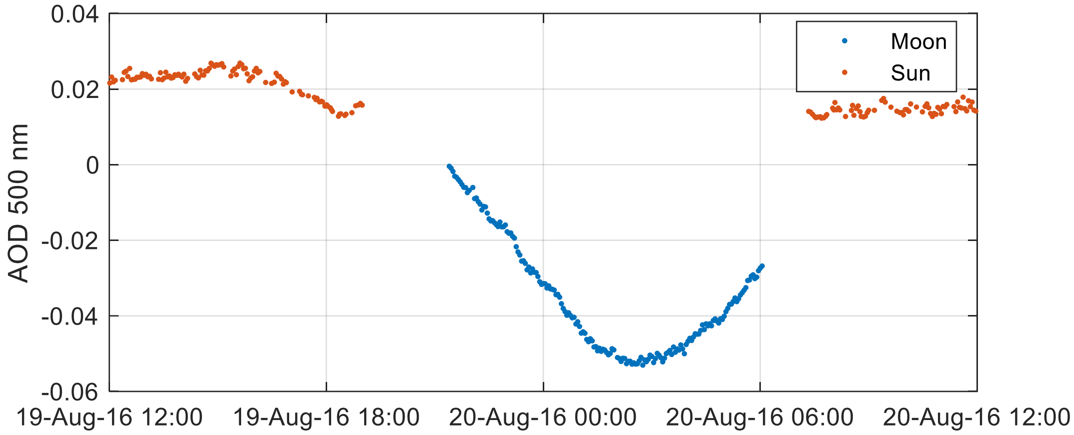

Figure R1: Aerosol Optical Depth (AOD) at 500 nm at daytime and night-time without RCF correction using Gain calibration method at Izaña (Spain) from 19 to 20 August 2016.

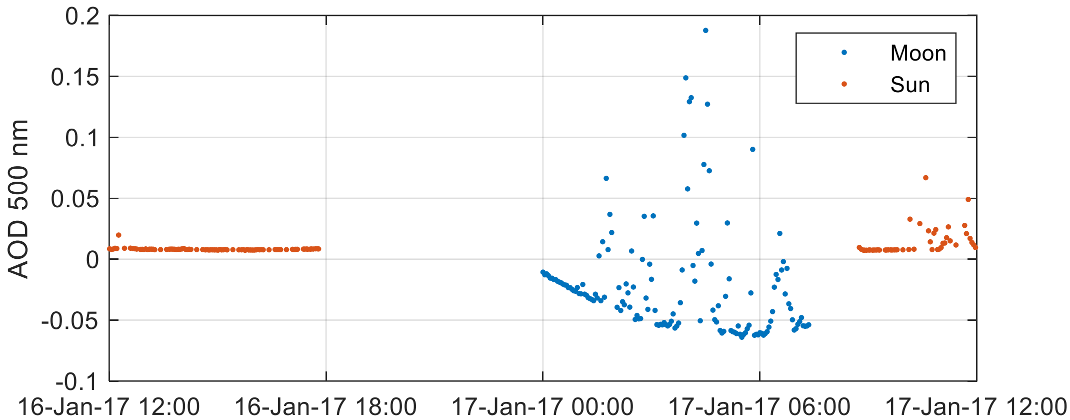

Figure R2: Aerosol Optical Depth (AOD) at 500 nm at daytime and night-time without RCF correction using Gain calibration method at Izaña (Spain) from 16 to 17 August 2017.

RC: Lines 257-259, "These differences point out negative values in the calculated AOD with Gain method and RIMO model, and the existence of a fictitious nocturnal cycle, symmetrical with the optical airmass, which could be associated in Sun photometry to a deficient calibration" This sentence doesn't make sense. "point out" should be "suggests that"??

AC: The sentence has been modified as:

"*These differences show negative values, which is because the calculated AOD with Gain method and RIMO model is mostly below zero. A fictitious nocturnal cycle, symmetrical with the optical airmass, appears in these differences, and hence in the calculated AOD* *with Gain method and RIMO; this kind of fictitious cycle are usually associated in Sun photometry to a deficient calibration (Cachorro et al., 2004, 2008; Guirado et al., 2014)*"

RC: Lines 262-263, "Assuming the Gain calibration and AODref are right," What do authors mean by "right"? I assume that the authors want to say that "Assuming the Gain calibration and AODref are accurate"??,
AC: The referee is right. We have replaced "*right*" by "*accurate*" in the new manuscript version.

RC: Line 298, "MPA absolute values lower or equal to 55 since" Any reason for picking 55 degree as the threshold?
AC: This threshold was based on the observation of RCF data. 340 nm is too noisy, but the dispersion is even greater for MPA absolute values above 55º, where the low lunar irradiance signal makes the signal to noise ratio too low. Anyway, we recommend that this channel is not used.

RC: Line 345, What is the study period for Figure 3?
AC: The period encompasses 2016 and 2017, it is the full period with star photometer data used in this work. This has been added in the Figure caption:
"Figure 3: *Aerosol optical depth (AOD) and Angström Exponent (AE) from Moon photometer versus the AOD and AE from star photometer for 2016-2017 period and for different wavelengths. Colour legend represents the relative density of data points. Black lines indicate linear fit to the data*"

RC: Line 345, for a comparison purpose, can the authors also add a plot that is similar to Figure 3 but without using the RIMO RCF (e.g. using the original RIMO model)?
AC: Figure 1 already shows that AOD presents wrong values when RCF is not applied. Hence, we do not consider that a similar analysis but with data that we know is wrong helps to improve the paper clarity. In addition, the automatic AOD cloud-screening will not work well with these data and we would need to transfer the cloud-screening results of the AOD calculated with RCF to the AOD without RCF correction. Nevertheless, we have done the comparison and it is shown in the Figure R3. As can be observed, the AOD from Moon underestimates about 0.05 the AOD from stars if the RCF correction is not applied. It is clearer in the Figure R4, where the differences are represented as a function of the MPA.

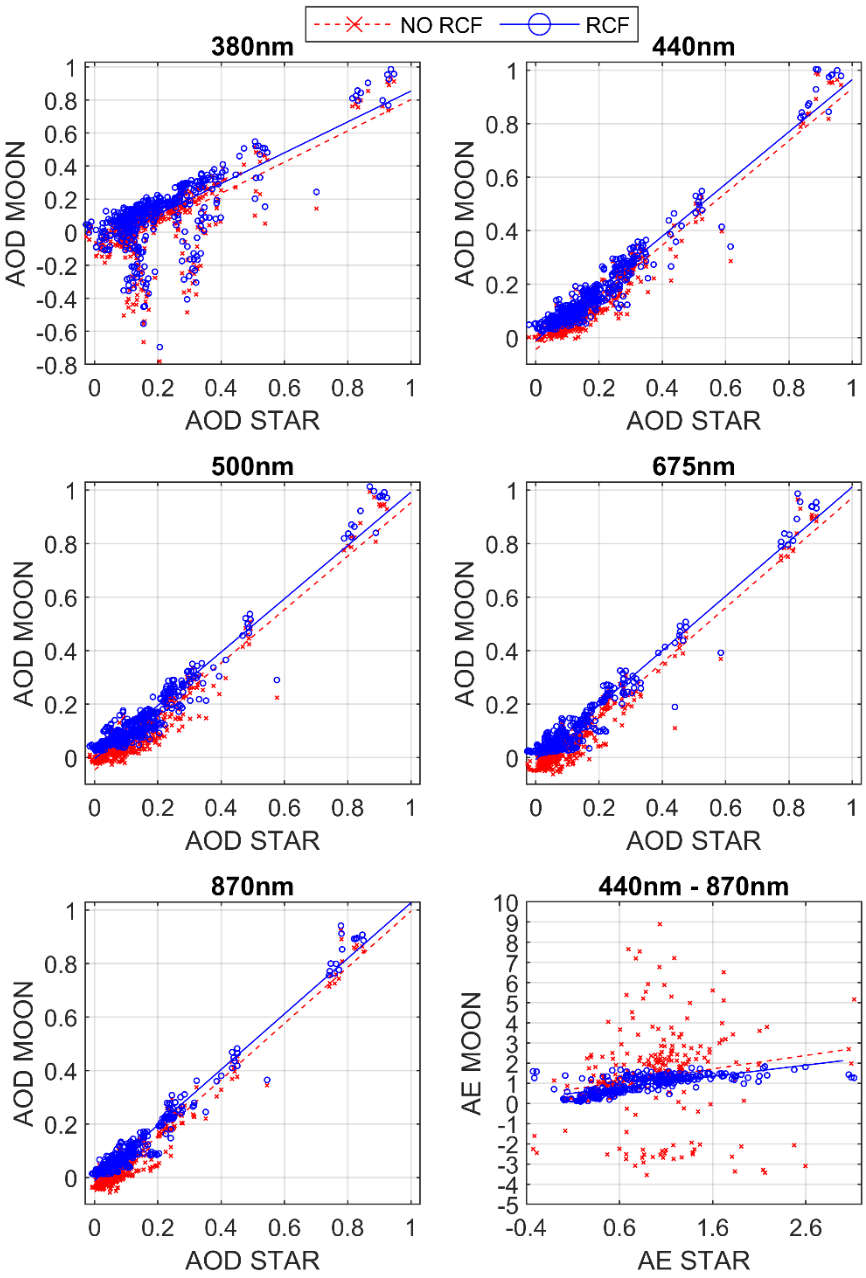

Figure R3: Aerosol optical depth (AOD) from Moon photometer with and without RCF correction versus the AOD from star photometer for 2016-2017 period and for different wavelengths. Linear fits are also represented for each wavelength.

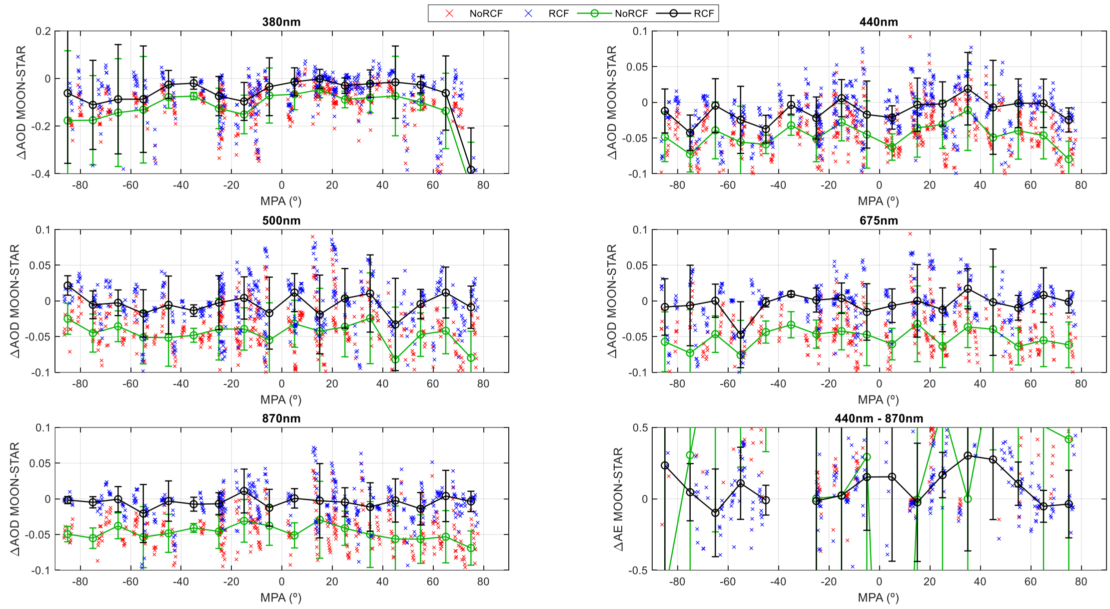

Figure R4: Aerosol optical depth (AOD) differences between the Moon and star photometers as a function of Moon phase angle (MPA) for different wavelengths. Bottom-right panel shows these differences for Angström Exponent (AE) in the 440-870 nm range. Black circles represent the median of all differences in a ±5º MPA interval, while error bars indicate ± standard deviation of the data in the same interval.

RC: Lines 359-360, what are the causes of the negative values? Can figure 3 be modified to include negative AOD values?

AC: The manuscript explains that there are some problems with the 380 nm channel. Moon irradiance is low and then this channel is noisy with a low signal to noise ratio, especially for high MPA values. In fact, the paper recommends not to use of this channel for these reasons. The other wavelengths do not show these negative values; hence, the Figure 3 has been divided in 6 panels (one per wavelength and one more for AE) in the new manuscript (see Figure R5). Now the negative values in the 380 nm channel are shown while the other channels maintain the previous axis limits, so that all data are displayed. In addition, the scatter plots have been replaced by density scatter plots, adding the density of data points through a colour legend.

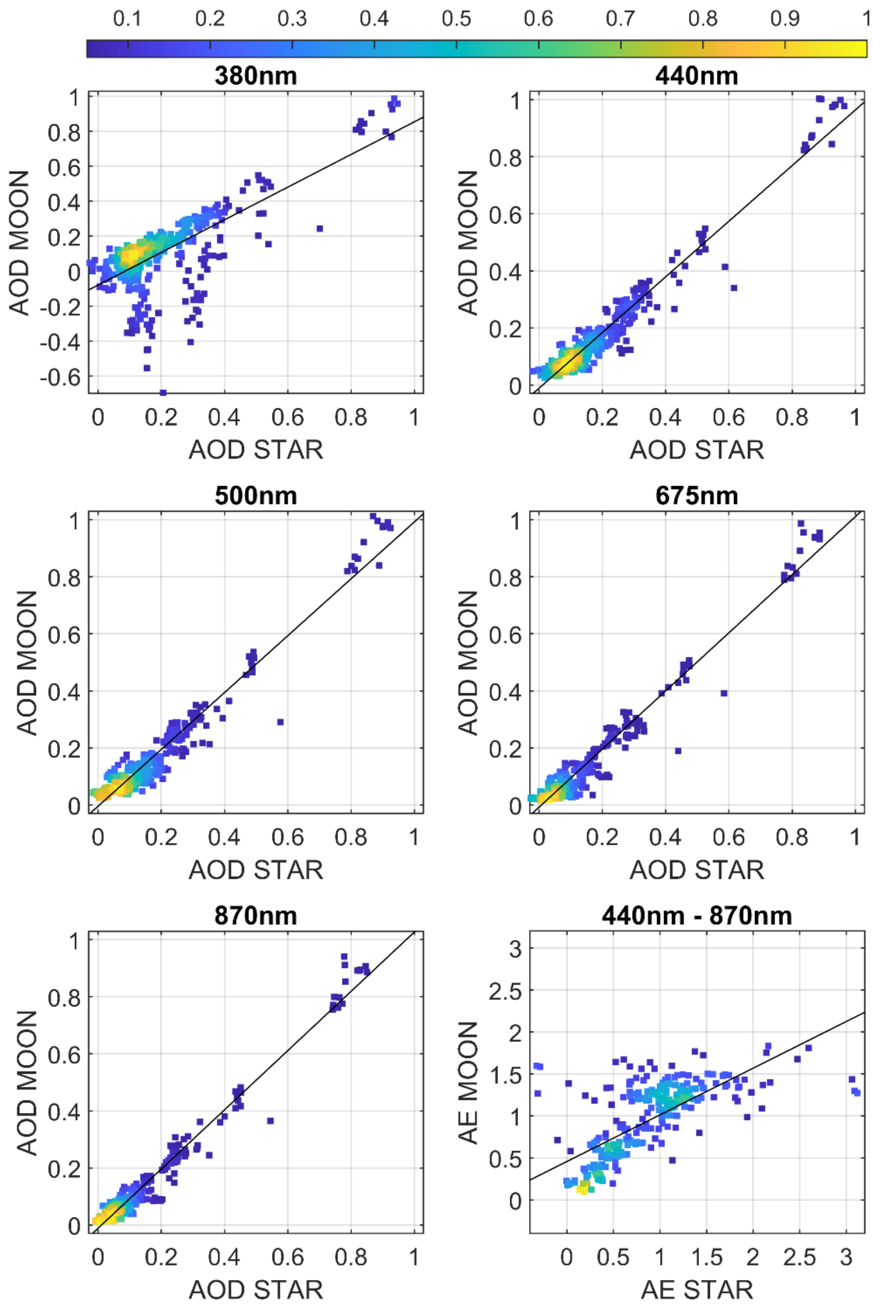

Figure R5: Aerosol optical depth (AOD) and Angström Exponent (AE) from Moon photometer versus the AOD and AE from star photometer for 2016-2017 period and for different wavelengths. Colour legend represents the relative density of data points. Black lines indicate linear fit to the data.