

Interactive comment on “Calibration of an all-sky camera for obtaining sky radiance at three wavelengths” by R. Román et al.

Author’s answer to Anonymous Referee #3

The authors greatly acknowledge the anonymous reviewer (Referee #3) for carefully reading the manuscript and providing constructive comments and an interesting discussion about the validity of the method.

1-General comments

In general, Referee #3 proposes two questions: Is the method proposed correct? and, secondly, are the errors acceptable for reliable applications? Basically, the well-reasoned conclusions of the referee are: the method is correct but its errors are too high to retrieve aerosol properties. We agree with the referee, and, in the new version of the paper, we have pointed out that method’s errors are too high to that goal. Nevertheless, we think that a comparison of some retrieved properties using CIMEL and camera could be interesting in the future, at least in the fine mode. Regarding coarse mode this comparison has not sense, because, as the referee states, the short spectral range of the camera is unsuitable for an adequate retrieval of aerosol properties. Therefore, we think that the camera wavelengths could be useful to estimate aerosol properties of the fine mode (higher wavelengths are needed to retrieve the coarse mode), however the radiance errors look too high to this end.

The referee asks about the reasons why the authors didn’t use the method by Olmo et al., (2008) (Applied Optics). In the mentioned paper the AOD was calculated using spectral sky radiances in the range of 380-780 nm retrieved with the method presented in López-Alvarez et al. (2008), whereas in this study we use only 3 wavelengths. In addition, our method does not need a training process and, therefore, the results are obtained in a way that has physical meaning.

We agree with the referee when he/she argued that our method is a risky alternative, and the use of a sphere in the laboratory is more reliable. Unfortunately a sphere is not available for us. Thus, the use of a radiative transfer model is a good option when there

is not an alternative way to calibrate a system like a sky camera. In addition, as the referee claims, the direct use of CIMEL radiances to calibrate is not easy to implement and this doesn't assure lower errors. In fact, a lot of pixels will be non-calibrated using the direct method proposed by Referee #1.

Regarding the dependence on the SZA, maybe, more images would help us to find a clearer dependence, but the results obtained using the 8 days give a smooth dependence (in fact we observed a small increase in the variation between the K_{ij} coefficients with SZA). Additionally, we think that the non-dependence on SZA of K-matrix is a good approximation, showing good results. Therefore, in our opinion, the use of 8 full days is enough.

Finally, we would like to remark one sentence given by the referee, which summarizes the answer to the two questions given at the beginning of this report:

“In my opinion the methodology applied and the obtained results are correct but the high associated errors are inherent to the method because of the characteristic of this instrument”.

On the other hand, the referee proposes the change of azimuth angle by scattering angle. The problem is that, now, we have not 50 measurements for the same angle and, therefore, we must use scattering angle bins (each 5° , for example) for almucantar. Thus, we have represented Fig. I (at the end of this report), showing the differences as a function of the scattering angle instead of the azimuth angle. Moreover the bias has been included in this figure according to the suggestion given by the Referee #2. Fig. 3 will be changed by Fig. I if the paper is accepted. Fig. II includes the differences (ARE and bias) between the CIMEL and camera as a function of scattering angle instead azimuth or zenith. Fig 5 could be changed by Fig. III (removing the previous panels g and h) and Fig. II could be added as a new Fig. 6 (the previous Fig.6 will be Fig. 7). If these new figures will be included in an improved version of the paper, the comments respect ARE values as function of azimuth will be changed for similar comments but taking into account the scattering angle.

2-Relevant vagueness

Referee Comment #1: The introduction contains a lot of unnecessary sentences which are not directly related to the subject of the paper (and hence the related references). Certainly the solar radiation is the responsible of sky radiance but most of the references on solar radiation characteristics are superfluous. The whole introduction must be shortened.

Authors response #1: We structured the Introduction following the next criteria:

- 1- An introductory paragraph to the solar radiation and the origin of sky radiance by scattering process. We considered this paragraph important to understand the basic process of radiance and its directionally coming to the surface.
- 2- A paragraph about aerosols effect on solar radiance, and how the radiance is useful to the knowledge of aerosol properties.
- 3- A similar paragraph to the previous one, but related to the clouds since sky radiances and camera are useful for both aerosols and clouds.
- 4- A revision of the literature related to measurements and properties of sky radiance.
- 5- A state of the art of the use of sky cameras is necessary to understand the device used in the paper and how is used by other authors.

We would like to include all these points because we think they are useful and necessary to introduce our work. Therefore, we think the introduction should not be modified.

Referee Comment #2: The paragraph describing the inversion strategy in the introduction is mostly wrong (page 1875, lines 15-25). For example, the sentence "different authors (e.g. Nakajima et al. 1996; Dubovik and King, 2000) proposed an inversion algorithm for the retrieval of aerosol optical properties using sky radiance measurements in the almucantar" is false...

Authors response #2: This comment has been taken into account and a new paragraph will read as follows:

“The sky radiance depends on aerosol optical properties and thus these properties can be derived from sky radiance measurements. In this sense, different authors (e.g., Nakajima et al., 1996; Dubovik and King, 2000) proposed inversion algorithms for the retrieval of aerosol optical properties using measurements of sky radiance. Dubovik et al. (2006) and Olmo et al. (2008b) include non-spherical particles approximation in the inversion codes of Duvobik and King (2000) and Nakajima et al. (1996), respectively, to obtain the columnar aerosol size distribution, the single scattering albedo (SSA), the phase function (PF) and the asymmetry parameter from radiance measurements. To this end, Olmo et al. (2008b) used the sky radiance in the principal plane (the plane perpendicular to the horizon that crosses the solar zenith angle, SZA, and zenith). Therefore, measurements of sky radiance are also useful to retrieve the aerosol optical properties”.

Including the next reference: “Dubovik, O., Sinyuk, A., Lapyonok, T., Holben, B. N., Mishchenko, M., Yang, P., Eck, T., Volten, H., Munoz, O., Veihelmann, B., Van Der Zande, W. J., Leon, J., Sorokin, M. and Slutsker, I: Application of spheroid models to account for aerosol particle nonsphericity in remote sensing of desert dust, J. Geophys. Res. Atmos., 111, D11, 2006”.

Referee Comment #3: In the section 3.2, the authors propose a comparison of 50 almucantar cloudless measurements with modeled radiances in order to study the reliability of the UVSPEC. This comparison shows errors higher than 20% (for 677nm) for short azimuth angles. These high differences are justified in the text by the presence of clouds in the measurements, which contradicts the conditions settled in the beginning of the section. On the other hand, in the last paragraph of the section the authors conclude that the sky radiance estimated by the UVSPEC model, used afterwards as reference for the calibration of the all-sky camera, is in agreement with experimental measurements. This affirmation is too generous since as it can be directly observed looking at the figure 3, ARE is only lower than 8% for 441nm channel between 10 and 50 and for 677nm for angles larger than 60.

Authors response #3: The sentence claiming presence of clouds will be deleted. The too generous affirmation must be changed, and a new paragraph will read as follows:

“Therefore, the sky radiance estimated with the UVSPEC model, and used in this work as reference for the calibration of the All-sky Imager presents differences with respect to the experimental ones smaller than 20% and 10% for 441 nm and 677 nm, respectively. Nevertheless, we have decided to avoid the use of the UVSPEC simulations for those cases near to the sun (azimuth angle relative to sun smaller than 10°)”.

3- Other specific comments

Referee Comment #4: As the section 2.3 describes the input values to model the radiance the name "Data" is quite ambiguous and should be replaced.

Authors response #4: The section 2.3 could be replaced by “Data-set”. The radiances and the images used (recorded during the year 2011) are described in this section (not only inputs), therefore we think that the name “Data-set” is appropriated, because the section describes all data used in the paper.

Referee Comment #5: Page 1874 in the abstract, line 13, “The comparison between the output signal.,” I think that use the word “comparison” in this sentence is not adequate, rephrase this sentence.

Authors response #5: Maybe this word can be replaced by “relationship”:

“The relationship between the output signal of the All-Sky Imager and the modelled sky radiances provides a calibration matrix for each image”.

Referee Comment #6: A few spelling errors have been found along the text, although they are not so much relevant.

Authors response #6: We will remove all spelling errors in the revised version.

Referee Comment #7: Page 1882, line 6. To use implemented in this sentence is wrong. Rephrase this sentence.

Authors Comment #7: According to the reviewer’s suggestion, the sentence will be:

“We run the UVSPEC model using the standard profiles and inputs indicated by Antón et al. (2011b) for the GFAT station at Granada”.

4- Figures

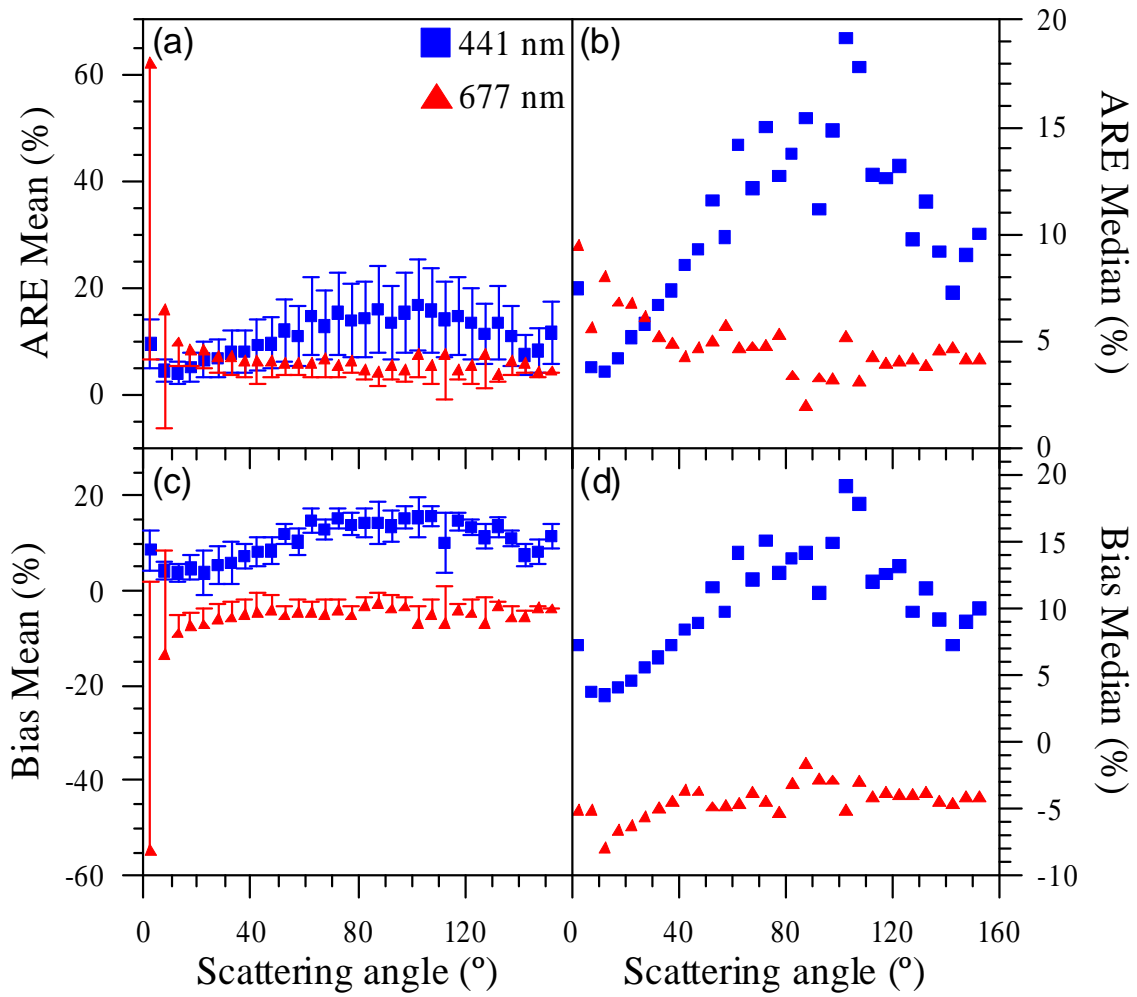


Figure I. Mean (panel a) and median (panel b) of the absolute relative error and bias (panel c and d) for 441 and 677 nm as a function of the scattering angle in the almucantar. The error bars represent the standard deviation, which only the half (up or down) is included for 677 nm due to the high values near to the sun.

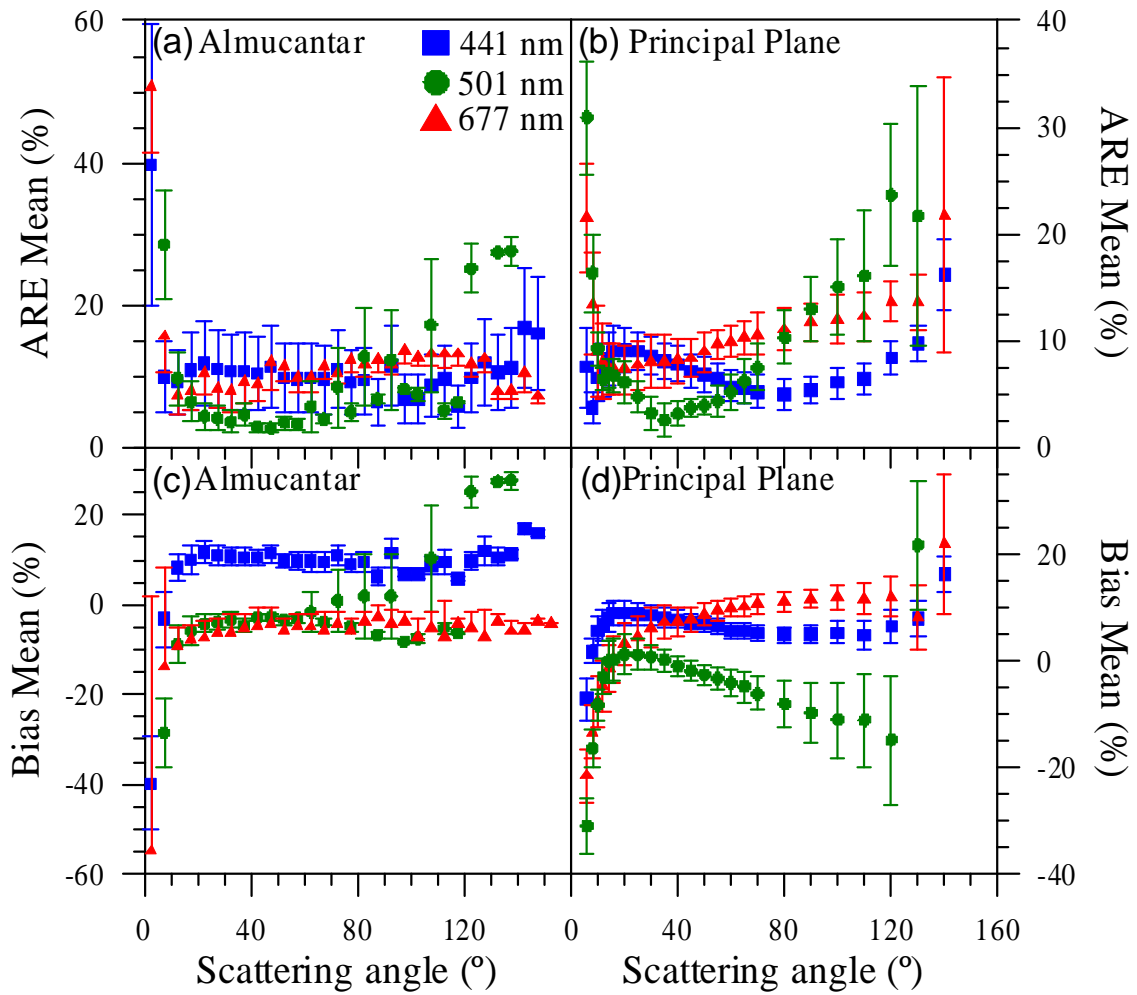


Figure II. Mean of the absolute relative error (panels a and b) and bias (panels c and d) for 677 nm, 501 nm, and 441 nm as a function of the scattering angle. Left panels represent almuquantar and right panels are principal planes. The error bars represent the standard deviation, which only the half (up or down) is included for 677 nm (almuquantar) due to the high values near to the sun.

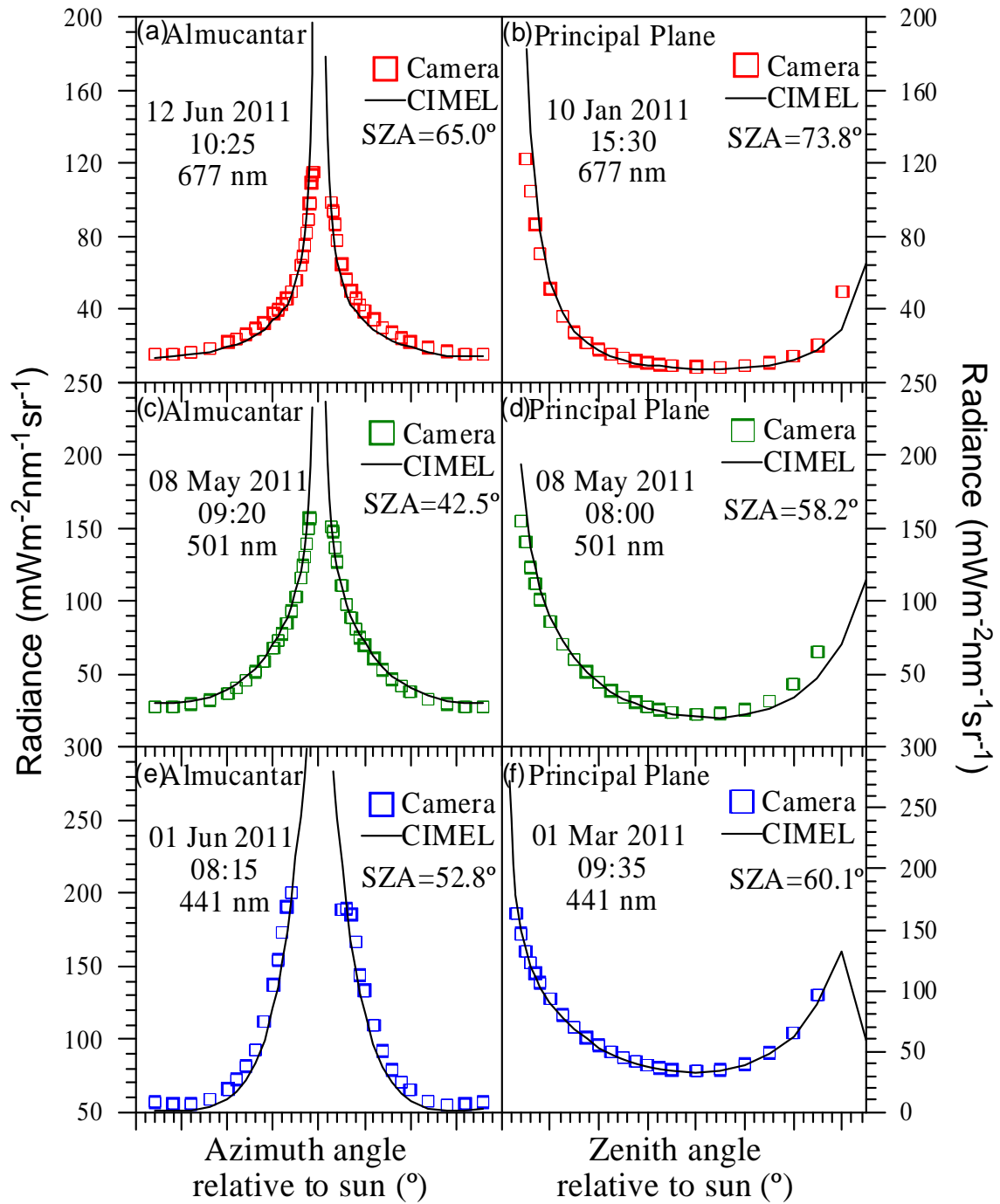


Figure III. The CIMEL and camera sky radiances together for two different dates at 677 nm (panels a and b), 501 nm (panels c and d) and 441 nm (panel e and f). Left panels represent almicantar and right panels are principal planes.