Response to comments of Reviewer 1

Authors would like to express sincere thanks to an anonymous reviewer for his/her valuable comments. We revised a manuscript very carefully based on given comments. The comments of the reviewer are in blue, our replies are in black, and changes made in the revised manuscript are in red. Our replies to the comments are as below.

The article entitled Retrieval of cloud properties from sky radiometer observed spectral zenith radiances, by P. Khatri, H. Iwabuchi, T. Hayasaka, H. Irie, T. Takamura, A. Yamazaki, A. Damiani, H. Letu and Q. Kai presents and validates a method for retrieving cloud properties (i.e. cloud optical depth and Cloud effective radius) from zenith radiance measurements of the sky, performed from ground with a commercial available sun-sky radiometer Prede POM02.

The article is considered important and presents a method that means a step forward in the establishment and improvement of ground based methods for the observation of cloud properties, that are one of the most important factors in the Earth climate. The establishment, validation, and further improvement of the method will allow other users of the Prede POM02 sun-sky radiometer, particularly users of the SKYNET international network, to obtain relevant information and contribute to this field of research. The study is considered adequate for this journal. However, the article would benefit of a final revision by a native English speaker.

➔ Thank you for your encouraging comments. The revised manuscript has been read by a native English speaker.

Specific comments:

- Abstract, line 17: the procedure of deriving calibration constants from another instrument could be called "calibration transfer method".

➔ It is done in the revised manuscript.

- Line 34-35: please rewrite sentence ("unlike advancements"?)

➔ Those sentences are rewritten as below.

Compared with the routine observation of aerosols through surface networks, such as AERONET (https://aeronet.gsfc.nasa.gov/) and SKYNET (http://atmos3.cr.chiba-u.jp/skynet/), observation of clouds from the surface is performed at a limited number of stations and most of the observation data are not easily accessible.

- Line 47: not sure "tally" is the most appropriate word here

➔ We rewrote the sentence as below.

The fundamental idea is to compare the observed signals with LUT data corresponding to prior known cloud optical depth (COD) and cloud particle effective radius (CER) while finding a plausible solution for the COD and CER combination.

- Line 80: you have included 940 nm channel in the list of channels used for aerosol retrieval?

➔ It is corrected in the revised manuscript.

- Line 89 and 91: instead of "alternation", "alternative" could suit best

➔ It is done in the revised manuscript.

- Line 92: rewrite "A more detailed study about..."

➔The typo mistake has been corrected. In the revised manuscript, the sentence appears as

A more detailed study about sky radiometers and their calibrations can be found in Khatri et al. (2016).

- Line 96-98: authors state that 2.2um channel is not used because the longest wavelength used by AERONET is 1.627um, but Cimels are not used in this study. Do the authors plan to apply the method on Cimel instruments in the future? Otherwise, I think it is not well understood the reason for rejecting this channel.

➔We clarified the reasons in the revised manuscript as below.

We use sky radiances (*E*) observed at three longer wavelengths (0.87, 1.02, and 1.627 µm), excluding 2.2 µm, which is not used for two main reasons. First, our statistical analysis suggests that the number of unphysical data (observation data recorded as 0) for 2.2 µm is high; thus, 2.2 µm is excluded to increase the retrieval number. Second, the longest wavelength used by AERONET is 1.64 µm; so the proposed algorithm could be easily used for sun photometer observed data as well. Wavelengths shorter than 0.87 µm are not used to avoid the effect of aerosols as far as possible.

- Line 103: "from the solar disk scan during very clear sky days"

➔ The sentence is corrected as suggested by the reviewer as

$\Delta\Omega$ for 0.87, 1.02, and 1.627 μm can be determined from the solar disk scan during very clear sky days (Nakajima et al., 1996)

- Line 105: "wavelengths"

➔ The typo mistake is corrected in the revised manuscript.

- Line 111: "very mere" -> very small

➔ A correction is made as suggested by the reviewer in the revised manuscript.

–Line 113: do the authors expect any limitation in the method for cases of dust mixed with clouds due to non-sphericity?

➔We used aerosol data of very clear sky days while determining the calibration constant (F_0) values using the proposed method. Thus, there is a very little chance of mixing clouds with aerosols as suggested by the reviewer. However, even if some cloudy data have been misinterpreted as aerosols by a cloud-screening procedure, such cloudy data can get filtered because the proposed method eliminates the outlier that decreases the correlation coefficient between lnF and τm (F, τ, and m are measured direct intensity, total optical thickness and optical air mass, respectively) through an iteration process until a very strong correlation ($r \geq 0.997$) is obtained.

–Line 116: Beer-Lambert

➔ The typo mistake is corrected in the revised manuscript.

- Line 120: do the authors use any minimum number of data points to perform a successful final IL fit? Any other threshold or criteria?

➔ There is no specific condition regarding minimum number of data points because each final IL plot is visually inspected to confirm that suspicious data points are not included and there are enough number of data points in the fit.

The proposed method was designed by putting other criteria, such as the maximum value of aerosol optical thickness (AOT) and solar zenith angle, as well. However, our test indicates that such criteria can have a very less influence in overall performance because the outlier is removed through iteration as explained in the reply of the previous comment. Thus, criteria other than the value of correlation coefficient are removed.

- Line 129: "temporal variation of lnF0"

➔ The sentence is corrected as below.

Thus, the proposed method can be used to determine temporal variation of $lnF_{0,1.627}$, which is useful for analyzing long-term observation data by mitigating the filter degradation problem.

- Line 154-155: "calculated for COD and CER in the intervals 1-64 and 2-32 respectively, with steps of 1"

➔The sentence is corrected as below.

The retrieval errors are calculated for COD and CER values in the ranges of 1–64 and 2–32 µm, respectively, in steps of 1 µm.

- Line 160: the assumed error of 1.0 cm for PWC looks like a very high upper estimation of error. Is it a typo error?

➔ There was no typo mistake. We assumed error value of this magnitude to better understand the algorithm performance.

- Lines 169-203: it is a long paragraph. Perhaps it could be divided at lines 183 and 191

➔ It is done in the revised manuscript.

- Lines 213-214: do the three percentages correspond respectively to percentiles 5, 50 and 95?

➔ Yes, they are according to the reviewer. The English writing of the revised manuscript has been polished by a native speaker. Thus, each sentence is expected to have a clear meaning in the revised manuscript.

- Line 217: comparison, not compassion

➔ This typo mistake is corrected in the revised manuscript.

- Line 221 (section 5.1). Is the NA radiometer a pirheliometer? Is it pointing at nadir direction continuously? Does it really measure radiance, or irradiance? I think it would useful to have some more details about the instrumentation used here.

➔ The description is elaborated in the revised manuscript as below.

The broad-band radiance and irradiance of the shortwave spectral range (0.3 – 2.8 µm) observed using a narrow-angle radiometer (EKO Instruments Co., Ltd., Japan; FOV: 5°) and a pyranometer (Kipp and Zonen, Netherlands; FOV: 180°), respectively, at Chiba (35.62°N, 140.10°E) every 20 s from December 2015 to December 2016 are used to evaluate the cloud properties observed by the sky radiometer. The narrow-angle radiometer observes the downwelling irradiance signals as voltage in a narrow FOV. The instrument was calibrated by the manufacturer in the laboratory, and the observed signals are converted into radiance (unit: $W/m^2/sr$) by using the company provided calibration constant value. Because the narrow-angle radiometer faces upward, thus obtained radiance is from the zenith.

- Line 236: "highly qualitative"?

➔ "qualitative enough" is used instead of "highly qualitative" in the revised manuscript.

- Section 5.2.: in order to better understand the improvement of the comparison respect to Kathri 2018, a short mention to the previous results using all the database would be useful

➔As suggested by the reviewer, a new paragraph is added in section 5.2.

Although the qualitive information reported by Khatri et al. (2018) and the comparisons in Figures 7 and 8 of this study are similar, there are differences in Figures 7 and 8 with the comparison plots shown in Khatri et al. (2018). The application of data screening criteria in this study generally screened out data with large differences between the sky radiometer and satellite sensors. These large differences in the previous comparison probably arose from the different FOVs of the satellite sensor and sky radiometer, while observing inhomogeneous clouds. Thus, the comparison results presented in this study by addressing the cloud inhomogeneity problem more logically should give more accurate and refined information than those presented in Khatri et al. (2018).

Figures: - Line 270: Figures 7a and 7b

➔ The typo mistake is corrected in the revised manuscript.

- Line 276: Figures 8a and 8b

➔ The typo mistake is corrected in the revised manuscript.

- Figure 4: I understand that figures a, b, c correspond to channels 870, 1020 and 1627. But I do not understand what are zenith and azimuth angles respectively. If both zenith and azimuth results are the same for figures a and b, but are slightly different for figure c, please state that zenith and azimuth angles are represented with different colors.

➔The zenith and azimuth angles are exactly same for Figs. 4a, 4b, and 4c. Since the transmittance changes with the solar position, we choose solar zenith and azimuth angles of 30° and 0° as representative to investigate how the transmittances of 0.87, 1.02, and 1.627 μm change with the changes of COD and CER. Therefore, the solar zenith and azimuth angles are indicated in the caption.

If Fig. 4c is viewed very carefully, the contour lines denoted by different colors for 2 < COD < 5 and CER > 4 μm appear again for ~2 < COD < 4 and CER < 4 μm. It is technically difficult (due to not sufficient space) to write the values of transmittances within the contour lines (similar to Figs. 4a and 4b) in the second domain, i.e., ~2 < COD < 4 and CER < 4 μm. Therefore, different colors are used to resolve this technical difficulty.

References

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