

Interactive comment on “Investigation of the accuracy for single scattering albedo retrieval from global UV irradiance measurements” by S. Kazadzis et al.

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Response to the reviewer #1. “Investigation of the accuracy for single scattering albedo retrieval from global UV irradiance measurements” by Kazadzis S., Grobner J., Arola A. and Amiridis V.

We would like to thank the reviewer for his/her useful comments.

General Comments

About the accuracy of AOD and other aerosol optical parameters that are used as inputs to the radiative transfer modeling: Text that was added to the Abstract.

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“Based on the fact that additional uncertainties would be introduced in the SSA retrieval from AOD model input accuracy, asymmetry parameter assumptions, we show that only very few instruments could be able to detect long term SSA changes.” Additional corrections in the text concerning this issue can be found in the specific comments section.

Discussing more on the non perfect cosine response of the instruments included in the analysis:

The Qasume instrument has an ideal cosine response so it is not affected from such errors. A number of instruments have also similar input optics. In addition there are some instruments with non ideal cosine response that apply a post correction to account for that error and a few that do not apply any correction. The deviations among such instruments with the QASSUME instrument are taken into account when calculating SSA differences from measurements differences (calibration + cosine errors+ other measurement errors). However since the analysis has not been separated for different solar zenith angle ranges we agree that SSA retrieved at high solar zenith angles is more affected in the case of instruments that have a non ideal angular response and do not apply a post cosine correction. There are several changes in the text mentioned in the specific comments about this issue. In addition to those, a text was added mentioning that:

“The SSA retrievals from results based on measurements of spectroradiometers with a non ideal angular response of their input optics are likely to be biased as measured UV irradiance is lower than true values at large SZA’s resulting lower inferred SSA than true values of SSA.”

Comparing the results of the direct-diffuse method by Krotkov and the GSI method proposed here:

We agree with the findings of Krotkov et al., 2005 and Bais et al., 2005 clearly demonstrate the advantage of using direct to diffuse ratios instead of total UV irradiances.

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In addition, the combination of CIMEL and UVMFR results in the study of Krotkov et al., 2005 demonstrates that in addition to the calibration “transfer” from the CIMEL to the UVMFR accurate RTM input parameters as the asymmetry factor are available for more accurate retrievals. The main idea behind the work was to demonstrate the limitations of trying to use such method based on the fact that there are too many spectroradiometers and long UV time series from those instruments worldwide. So such a study together with the availability of other instruments (e.g. CIMELS or other sunphotometers) at UV monitoring sites can be used aiming to enlarge the existing SSA at UV wavelength global measurements database.

A new text was added to the conclusions according to the reviewer’s suggestion:

“It is clear that the method of Krotkov et al., 2005a which is based on direct-diffuse ratio, has a significant advantage over the technique of using total UV irradiance due to the uncertainty in the irradiance measurements resulting from the calibration uncertainty. However, we decided to analyze the possibilities to use the GSI method because of the large number of UV monitoring station that have been performing global UV measurements from the start of the 90’s.”

Also text added in the in the conclusion section

“Summarizing, this work focuses on the possibility to use long term series of UV global irradiance measurements, in order to derive information on the SSA at various locations. Using comparison results of well organized campaigns we aimed to show realistic instrument differences, linked with absolute calibration, angular response and other measurement uncertainties. The uncertainty of deriving SSA from such measurements described, are linked not only with the measurement accuracy but also with the availability to use accurate RTM input parameters such as AOD, surface albedo, asymmetry parameter, ozone, NO₂. Other studies showed that using specific instruments or combination of instruments that can provide accurate knowledge of dimensionless transmittance, is sufficient for deriving SSA with a provided uncertainty. However, the value

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of this work/investigation is based on the fact that the number of spectroradiometers (or even UV broadband radiometers) providing absolute UV irradiance measurements from the start of the 90’s, could be used for the retrieval of aerosol SSA time series worldwide, with an uncertainty depending on each individual instrument. In addition, it has to be mentioned that the uncertainty of this retrieval is also influenced by the availability of measurements or accurate assumption of other RTM input parameters, mentioned above. As an example, the Brewer spectroradiometer Network could provide a valuable database of spectral UV measurements together with AOD retrieval (using their standard direct sun ozone measurement) in order to provide SSA information with relatively high spatial and temporal coverage.”

Specific comments

Page 1305, section 15. The Holben et al., 1998 reference together with the AERONET acronym as suggested. The sentence has been corrected.

Page 1306. Section 5-10. Suggestion has been taken into account. Text has been added : “All, methods of inferring the SSA at UV wavelengths require that the sky be completely cloudless since the radiative transfer model calculations are made for cloudless conditions. Completely cloudless sky conditions are not a common occurrence at many geographical locations, and obviously the data must be screened to eliminate partial cloud cover situations.”

Page 1307. Section 10: Additional information of the instruments visited has been added in the text. Different types, manufacturers and cosine response information were included in the new text: “The instruments that have been visited consisted of 20 double and 7 single monochromators. 15 of them were Brewer type spectroradiometers that are more easily comparable as they are used nearly the same way at all stations. Their absolute scale calibration procedures are based on measurements of calibrated 1000W DXW lamp sources and each individual local operator was responsible for the post correction data procedures including angular response (cosine

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correction) procedures (11 out of 17), stray light and wavelength shift corrections. 10 instruments were using Bentham double monochromators having similarities mainly on focal length of the monochromator and the entrance optics which have been manufactured to have a close to ideal (<1% for SZA<75o) angular response so they did not apply any cosine corrections. The two remaining instruments were a Jobin Yvonne and Dilor double monochromators with flat teflon as entrance optics, applying a cosine correction procedure.“

Page 1308, Section 15: Suggestion has been taken into account and new text added according to the reviewer recommendation: “However, for instruments that have no ideal angular response of their input optics and do not apply any correction procedures, cosine response errors, that are larger for higher SZA's, would bias the UV irradiance measurements and therefore bias the SSA retrieval at higher SZA's.”

Page 1308, section 25. Text added in order to define wavelength ranges shown in figure 2: “Results shown in figure 2 represent mean irradiance differences at 310-325 nm (UVB) and 325-350 nm (UVA).”

Page 1309, section 5: A paragraph has been added in order to describe the reasons for the sources of uncertainties of the spectroradiometers and their impact on the comparisons described in this work: “More specific concerning absolute irradiance differences: The standard deviations of the 27 instruments compared with the QASUME instrument of 3% in the UVA and 4% in the UVB can be mainly explained by the uncertainties of the irradiance standards and their documented differences. If the instruments are split into two groups, those with state-of-the-art entrance optics with low cosine errors and those that apply a cosine correction on the one hand, and the remaining instruments on the other hand, the average variability of 5.9% for the first group is significantly lower than the variability of 7.6% of the second group of instruments, which can be explained by the known and observed diurnal variations induced by a non ideal angular response. Concerning wavelength shift errors: The largest average wavelength shifts of up to 0.3 nm are seen with a Bentham spectroradiometer, while the worst case for a Brewer

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spectroradiometer has a wavelength shift of 0.06 nm. So Brewer spectroradiometers using their standard operating procedures appear to have a much lower wavelength uncertainty than most other spectroradiometers in this study. Concerning stray light errors: Only single Brewers showed such problems showing average (as the following percentages are SZA and ozone dependent) stray light contribution of 1% and 11% for 305 nm and 302 nm irradiances respectively.”

Page 1309, section 20-25: Suggestion has been taken into account. Text added: “Using satellite aerosol AOD information or other model based AOD databases, the uncertainty increases due to spatial AOD features especially at urban areas and temporal AOD variability that can not be easily provided with these means. In addition, using AOD information from measurements at the visible range and extrapolating to the UV wavelength range using an Angstrom exponent introduces an additional uncertainty due to non-linearity in the AOD versus wavelength relationship (Eck et al., 1999).”

Page 1310. Results and conclusions: The SSA retrievals from results based on measurements of spectroradiometers with a non ideal angular response of their input optics are likely to be biased as measured UV irradiance is lower than true values at large SZA's resulting lower inferred SSA than true values of SSA. For the case of the QASUME reference instrument and the majority (20 out of 27 instruments) this is not the case as they are either equipped with ideal in terms of angular response input optics or they apply correction procedures in order to eliminate such errors.

Page 1311, section 15-20: To the section referring to AOD uncertainties the recommendation was added: “Calibrated sun-photometers can provide AOD measurements with an uncertainty of 0.01 – 0.02 (Eck et al., 1999).”

Page 1311, section 20: A new text was added in the conclusion section “Assymetry parameter, aerosol profile and extraterrestrial spectrum uncertainties: For the comparison of all spectroradiometers with the QASUME and ths SSA retrieval we have used the same aerosol optical parameters for both instruments. SO, the present method-

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ology does not include information on the uncertainty included from such issues as their availability depend on the additional instrumentation of the individual UV monitoring site, that this methodology could be applied. For each site there is a need for a methodology to select appropriate values of spectral asymmetry factors that are representative of differing aerosol size distributions such as coarse mode desert dust or fine mode pollution or mixtures of the two. For example the presence of a sun-photometer (AERONET or other Network based), together with the UV irradiance spectroradiometer minimizes such uncertainties. A recent study (Ialongo et al., 2010) has been using the GSI method for the retrieval of SSA using UV global spectral measurements at solar (local) noon. In such studies due to the SZA variations during the year and also due to the AOD annual variations, the uncertainty for calculating the SSA is not constant (proportional to UV global irradiance measurement uncertainties), but depends on the SZA and AOD of each individual retrieval.“

Page 1312, section 15: The sentence was clarified as follows: “In parallel with the AOD effects, possible changes to aerosol absorption parameters would have also an additional feedback/effect on the calculated UV irradiance increase. “

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