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Interactive Comment

Interactive comment on "Improving the solar zenith angle dependence of broadband UV radiometers calibration" *by* M. L. Cancillo et al.

Anonymous Referee #1

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General comments:

The paper by Cancillio et al. presents a method for the calibration of UV broadband radiometers. It gives a comparison between several calibration methods which are currently in use, introduces a new method and provides a single test of three methods on a given dataset obtained during a calibration campaign in Spain, 2005.

The task of a calibration of broadband radiometers is to provide calibration coefficients to convert from the raw data of the radiometer to erythemally weighted irradiances. Therefore the most important step in any calibration method is the comparison of the radiometer output to a reference instrument, to obtain the absolute calibration factor C. However, two intrinsic properties of broadband detectors impede the conversion proce-

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dure. First, the spectral weighting function differs from the erythmal action spectrum. Second, the weighting of the solar radiation is only to a certain degree equal to the cosine of the incoming angle relative to normal incidence. In the UV wavelength range the resulting deviations introduce a dependence of the output signal of these instruments not only on the intensity of the receiving radiation but also on its spectral shape and on the atmospheric situation.

During the comparison to the reference instrument any change of the above mentions measurement parameters can be seen in a variability of C. Using only this single calibration factor will thus result in a significant uncertainty of the calculated irradiances. The strengths of the variability will depend first on the variation of the solar zenith angle (SZA), the total ozone column (TO3) and other atmospheric conditions (mostly clouds). Secondly it will depend on how much the spectral and angular response of the radiometer differs from the desired ideal cases.

In the paper two different calibration methods are distinguished: the one step and the two step method. In the later all the specific properties of the radiometer are directly taken into account. Next to the absolute calibration factor, the spectral and the angular response functions are obtained. From the former a conversion function, f, is derived which is a function of both, the solar zenith angle and the total ozone column. The second is used to calculate another correction function, coscor, which accounts for the imperfection of the angular response. This calibration method is recommended and gives the lowest uncertainties. In the one step method first only the absolute calibration factor is obtained. Further on the variability of C during the calibration period is studied. In the past the variability of the calibration factor was neglected. However, several 'one step'-attempts to treat this variability have been published, as stated in the paper. One described approach is, to run first a regression analysis over the data, to derive additional coefficients (C1 and C2) and to convert the data using a second order polynomial. This 'mathematical' solution does of course neglect the physical reason behind the variability of C. A further development of this method is to explicitly account

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for the strong diurnal dependence on the solar zenith angle by introducing the cosine function into the regression analysis. This method is the new calibration method, called 'angular method', presented by the authors.

For the test of the new calibration method three broadband radiometers where used; all three are radiometers from Scintec. One of the advantages of these instruments is their nearly ideal cosine response. In addition the deviation from the spectral response function to the erythemal weighting functions lead to a very low dependence of the conversion function f on the solar zenith angle and thus, the dependence of the absolute calibration factor on the solar zenith angle is very small. Using these instruments for the validation of the new 'angular' method is therefore the weakest possible test of the method. To illustrate the usability of the new calibration approach a validation with data from the widely used Yankee UVB-1 and Solar Light 501 radiometer is needed. It is likely that the proposed advantage of the angular method will vanish during these tests. Data from these instruments should be available from either the calibration campaign in the year 2005 or 2007.

The variability of the total ozone column during the test period is given with +-25 DU. This covers only 48% of the usual days at the measurement side. The transferability of the calibration to measurements under different ozone conditions is not discussed. This is especially important if the instrument is installed at a different measurement site, which is usually the case. No information and discussion is given on the atmospheric conditions (cloud amount). The transferability of the calibration coefficients, which are strongly influenced by the specific situation present at the calibration period, will always be a major problem with the presented calibration method, because the obtained calibration factors strongly depend on the conditions of the calibration period used for the regression analysis. This is the reason why the two step method has been developed. Any 'mathematical' approach cannot identify the intrinsic properties of the radiometers in test and can therefore only conceal the imperfection of the measurements - instead of the careful treatment provided by the two step method. One can conclude that the

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angular method is probably only useful to convert data for instruments with a negligible cosine error and a very small dependence of the conversion function on the SZA and TO3. The only advantage of the proposed method is that no spectral and angular response of the radiometer must be obtained.

The presented quality tests of the different methods are based on statistical numbers, i.e. the standard errors of the calibration factors. A figure showing the diurnal variability of the calibration factor would visualize the uncertainty of each calibration method for the full angular range. Such plots are very interesting for the analysis of the calibration factor for instrument with a larger cosine error like the Yankee UVB-1 radiometers. The discussion of the calibration uncertainty should result in an expanded uncertainty. It is composed of the points listed above and most of all the uncertainty of the reference measurement itself ($>$2%). For the 'two step' method an expanded uncertainty of 7% is expected for Scintec radiometers.

Specific comments:

17875, 13: Ozone measurements of very good quality are available from satellite data for all possible stations.

17876, 16: In respect to ozone measurements the calibration against Brewer #015 will be performed from IOS. However, the calibration for UV measurements will have been performed against the transportable reference spectroradiometer QASUME. The corresponding statement, result and reference are missing.

17877, 16: The uncertainty of calibration introduced by the extrapolation of the Brewer data to the full UV-range should be discussed.

17879, 24: Definition and reference for 'CIE' should be added.

17879, 26: The conversion function Ci(SZA,TO3) is normalized to its value at SZA=40 deg and TO3=300 DU (recommendation from 'A practical guide to operating broadband instruments measuring erythemally weighted irradiance' by Webb et al.).

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17880, 8, Equation 6: Incomplete cited (coscor etc).

17885, Table 1-4: Summarize the tables into one; the accurate listing of the result of all three radiometers is redundant.

17889, Table 5: Does not give any information, because no comparison is possible.

17891, Figure 2: More interesting than the relative differences would be a plot showing relative the ratios.

17892, Figure 3: Add this information into the ratio plot of Fig. 2.

Technical corrections:

17874, 11: 'In the last' - missing 'the' (very frequent error throughout the paper)

17875, 4: Change numbering (First,... Second,... Third,...)

17875, 7: 'to determine a matrix calibration', change to: 'to calculate a conversion function'.

17875, 19: 'Although a second-order method improving this angular characterization was proposed, certain dependence with the solar zenith angle still remains for those cases with low solar elevations.' - consider restructuring of the sentence.

17879, 4: 'Erythematic irradiance', change to: 'erythemally weighted irradiance'.

17880, 14: '...obtained applying...' change to: 'obtained by applying'.

17882, 6-7: Double declaration of MABE and MBE.

17880, 24 and 17885, Table 1-4: Units W/m2 V should be W/m2/V.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 17873, 2007.

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