Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2015-385-RC1, 2016

Atmospheric Measurement Techniques Discussions

Interactive comment on "The CU 2D-MAX-DOAS instrument - part 2: Raman Scattering Probability Measurements and Retrieval of Aerosol Optical Properties" *by* Ivan Ortega et al.

Anonymous Referee #1

Received and published: 13 February 2016

Review of the paper

'The CU 2D-MAX-DOAS instrument -part 2: Raman Scattering Probability Measurements and 1 Retrieval of Aerosol Optical Properties'

by Ivan Ortega et al.

The paper by Ortega et al. describes a new method for the determination of the aerosol optical depth and information on the aerosol scattering phase function from azimuth scans of spectrally resolved observations of scattered sun light. The method has two important advantages: a) it is based on the so called Ring effect, which can be retrieved with high accuracy without the need of an absolute radiance calibration. b) the

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Discussion paper

sensitivity of the method is particularly high for small AOD, for which other instruments tend to have large uncertainties.

The new method has the potential to improve AOD observations especially at low AOD. The paper is innovative, and the proposed method is well described and the first results are very promising.

I recommend publication in AMT after two major issues are addressed:

Major comments:

A) The authors describe the aerosol phase function by the Henyey-Greenstein parameterisation. This is a very simple parameterisation based on only one parameter. It is well known that true aerosol phase functions can not be well described by the HG parameterisation. Especially close to the forward direction, the deviations can become rather large. This is the range of scattering angles, which is explored in this study. I recomment that the authors repeat their radiative transfer simulations using more realistic aerosol phase functions (e.g. using Mie phase functions based on the sun photometer measuremens as input). If this is not possible, the authors should demonstrate that the use of a HG parameterisation in their study is justified.

B) A direct sun spectrum is used as Fraunhofer reference spectrum and the corresponding is determined by two different approaches. However, in my opinion, both approaches are based on false assumptions (see below). My suggestion would be to simply derive the RSP from radiative transfer simulations: Here I propose a simply procedure: 1) the radiance and the RSP are calculated for a scattered sun light observations in the direction of the sun. 2) the radiance of the direct sun is calculated for the same direction (the RSP for the direct light is assumed as zero). 3) The effective RSP is caluclated as the average RSP of both contributions (direct and scattered sun light) weighted by their respective radiances.

Reasons, why in my opinion both approaches in the paper are wrong:

On page 11, line 335 both methods are introduced: '(1) a Langley plot type method, where the dRSP obtained with direct sun spectra as reference spectrum is plotted as a function of the SZA, and (2) by interpolating the dRSP measured with small SRAA to the 0 degree (direct sun view).'

Method (1) is based on the assumption that the dRSP is a linear function of 1/cos(SZA). I expect that this is in general not the case.

Method (2) would only be justified if a smooth transition of the RSP between measurements of scattered and direct sun light could be expected. In my opinion this is not the case.

Minor comments:

Page 2, line 38: 'Active steps to minimize RSP in the reference spectrum help to reduce the uncertainty in RSP retrievals of AOD and g.'

I disgaree with this statement: Not the RSP value itself should be minimised, but rather the uncertainty of the RSP value. In the proposed method, RSP from measurements and simulations are compared. In this comparison, the absolute, but not the relative deviation between both data sets is minimised. This means that the uncertainty of the RSP of the reference spectrum should be minimised (but not the value of the RSP itself).

Page 4, line 97: 'The quantitative analysis of RRS by DOAS was introduced by Wagner et al. (2004, 2009a) with the so-called "Raman Scattering Probability. . .'

I think additional pioneering studies should be mentoned, e.g.:

Langford, A. O., Schofield, R., Daniel, J. S., Portmann, R. W., Melamed, M. L., Miller, H. L., Dutton, E. G., and Solomon, S.: On the variability of the Ring effect in the near ultraviolet: understanding the role of aerosols and multiple scattering, Atmos. Chem. Phys., 7, 575–586, 2007.

de Beek, R., Vountas, M., Rozanov, V. V., Richter, A., and Burrows, J. P.: The Ring effect in the cloudy atmosphere, Geophys. Res. Lett., 28, 721–724, 2001.

Vountas, M., Richter, A., Wittrock, F., and Burrows, J. P.: Inelastic scattering in ocean water and its impact on trace gas retrievals from satellite data, Atmos. Chem. Phys., 3, 1365–1375, 2003.

Page 6, line 154 : 'In this work, we focus only on the almucantar scan at solar EA.'

Why was this procedure chosen? If in addition, also measurements at other elevation angles were used (e.g. the scan at 45° EA) additional information could be obtained. (or the consistency of the results could be checked)

Page 7, line 191: RSP is not measured but retrieved

Page 7, line 204: 'Systematic errors in the retrieval of dRSP were quantified by means of sensitivity studies.'

Did the authors investigate the effect of instrument straylight (or its correction by the analysis software) on the RSP results?

Page 9, line 263: 'The sensitivity studies in Figs 3, 4, and in the supplement confirm that the RSP does not depend on the aerosol vertical distribution.'

This statement is based on measurements at rather high elevation angles. I expect that for measurements at low elevation angles (which are often used for MAX-DOAS observations) the RSP becomes dependent on the aerosol vertical distribution. The authors should discuss this aspect.

Page 14, line 408: 'The highest response in RSP to changes in AOD is observed at low AOD'

I am not sure if this statement is supported by the results shown in Fig. 7. The authors should possibly use linear scales. How exactly is 'response in RSP to changes in AOD' defined

Page 19, line 585: ‘The error in the RSP based retrieval of AOD and g is limited by the uncertainty about RSP contained in the reference spectrum.’

I think this statement is not supported by the shown results. In particular, I think the choice of a direct sunlight Fraunhofer reference spectrum is probably not the best choice, because the instrument response (in particular instrument stray light) is probably different for scattered and direct light observations. My suggestion would be to use a Fraunhofer reference spectrum of scattered sun light from the same measurement sequence (measured in zenith direction) and to simulate instead of the RSP the dRSP.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-385, 2016.