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Atmospheric Measurement Techniques Discussions

Interactive comment on "Determination of aerosol properties from MAX-DOAS observations of the Ring effect" *by* T. Wagner et al.

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Reply to referee 1

First of all we want to thank this reviewer for the positive assessment of our manuscript and the constructive and helpful comments. We followed most of the suggestions and give detailed explanations in (the few) cases where we disagree (see our detailed response below).

The paper addresses the relevant scientific question of whether Ring effect and O4 provide different information on the state of the atmosphere. This paper presents novel data. A substantial conclusion is reached on the information provided by the Ring effect with regard to the aerosol asymmetry parameter (not provided by O4 absorption).

The scientific methods and assumptions are valid. The description of experiments and calculations is sufficiently complete and precise to allow their reproduction by fellow scientists. The reader assumes a 1 km vertical grid is used in the RT model. The authors give proper credit to related work and clearly indicate their own new/original contribution. The number of references is very good. The quality of the references is appropriate, although it makes more sense to reference peer-reviewed journals than books, which are probably not refereed (e.g. Platt and Stutz, 2008). The title clearly reflects the contents of the paper. The abstract provides a concise and complete summary. The overall presentation is well structured and clear. The language is fluent and precise, except in a few instances (see technical comments below). Abbreviations etc. are correctly defined and used.

Reply: Many thanks for these positive comments. The vertical grid of the model is finer than 1km in the lower part of the atmosphere (to 50m below 200m, 200m below 12km, 1km below 25km and 2.5km below 50km). We added this information in the description of the radiative transfer modeling (section 3).

Scientific comments The speculation that Ring effect observations at large SZA might become a “well-suited tool” to retrieve stratospheric optical depth is questionable because, as the authors note, the stratospheric aerosol optical depth is rather small compared to the tropospheric aerosol optical depth and thus any changes in tropospheric aerosol optical depth would affect the retrieval of stratospheric aerosol optical depth. It is not sufficient to show that stratospheric aerosol optical depth changes are detectable, but that “interference” from changes in tropospheric aerosol optical depth can be separated or at least flagged.

Reply: In principle we agree with the referee about the potential interference of tropospheric aerosol (and clouds). However, in our opinion it should be possible to separate the influence of stratospheric aerosols from those of tropospheric aerosols and clouds. First, troposopheric aerosols (like clouds) are subject to a high temporal variability, but stratospheric aerosols change on rather long time scales. By investigating the temporal

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variability of the Ring effect measured at high SZA, it might be possible to extract the stratospheric signal. Part of the tropospheric aerosol signal can also be determined at smaller SZA (then the stratospheric influence is negligible) and the observations at high SZA could be corrected for the respective influence. However, these possibilities certainly need more research. We modified the text accordingly (in the abstract, section 5.3, and conclusions).

P741L11 "From these findings it is concluded that from observations of the Ring effect information on aerosol properties like optical depth, profile shape or asymmetry parameter can be obtained." The conclusion that profile shape information can be obtained is not supported by the observations. I suggest that the authors demonstrate this point further or remove the claim.

Reply: There might be a misunderstanding here: In Fig. 6a it is clearly demonstrated that especially for the low elevation angles, the aerosol profile has a strong influence on the Ring effect. We also added more discussion about this influence in the conclusions.

P741 After presenting their radiance and radiance ratio results, it would make sense if the authors also discussed whether the Ring effect offers more sensitivity to certain atmospheric information than these two observables. Currently, the discussion stops after contrasting information obtainable from Ring effect and O4 absorption.

Reply: We added a more detailed discussion in the conclusions: '...It was found that for most measurement situations the aerosol optical depth has by far the strongest influence on the observed quantities. However, several other parameters can also have a substantial influence on the quantities derived from MAX-DOAS observations. Here it is interesting to note that the different quantities show specific sensitivities to different aerosol parameters and should be used in a complementary way in future applications. The O4 absorption is mainly sensitive to the atmospheric light path distribution and is thus most sensitive to the aerosol optical depth and height profile. The Ring effect is also sensitive to the atmospheric light path distribution, but in addition it depends sys-

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tematically on the properties of the scattering processes. Especially for small relative azimuth angles Ring effect observations are sensitive to the aerosol phase function. The observed radiance is most sensitive to properties of the scattering processes, but is almost independent on the atmospheric light path distribution. In contrast to observations of the O4 absorption and the Ring effect, the radiance depends strongly on the aerosol absorbing properties (see also Frieß et al. [2006]).'

P734L15 "Like for the O4 AMF, the Raman scattering probability decreases in general with increasing aerosol optical depth." Some insight here explaining why this occurs for O4 AMF would add to this paper (...optional).

Reply: The reason for this dependency is that the light path along the line of sight depends strongly on the aerosol extinction. We added more information here: '. . .because of the decreased light path along the line of sight.' We also added more detailed information in the conclusions (see above comment).

Remaining technical comments:

Some of the figures should be redone so that, in particular, the y-axis range is almost fully utilized.

Reply: We agree that the y-scale in individual graphs is not always used in an optimum way. However, this was done by purpose in order to clearly indicate the different strengths to which the MAX-DOAS observations are influenced by changes of the atmospheric parameters. In this way it becomes immediately clear that some parameters have a strong, but others almost no influence on the MAX-DOAS observations: As an example, in Fig. 6 the surface albedo has only a very small effect compared to other parameters like the vertical profile.

As is done in Figures 4a-b, 9 and 10, Figures 3a-b and those in the appendix should have the bias removed (due to the reference spectrum). This makes the RSP seem like a more meaningful quantity. Figure 3 currently has negative measured RSP values

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(which of course is possible given that the reference spectrum contains Ring signature as well).

Reply: We agree, and in the revised version we made all figures consistent: we always added the amount of the Fraunhofer reference spectrum to the measured data.

Why is the panel for an elevation angle of 90_ left out of Figure 4d?

Reply: Since the radiance ratio is calculated with respect to the values for the 90° elevation, they are always unity by definition. Thus it makes no sense to show the 90° values for the radiance ratio.

"...independent on..." -> "...independent of..." (2 occurrences)

Corrected.

"...overview on..." -> "...overview of..." (2 occurrences)

Corrected.

P733L24 "...telecsope..." -> "...telescope..."

Corrected.

P736L18-19 "...because more photons are scattered from the side into the line of sight having a larger probability to be scattered on molecules." This is still not a sentence.

Reply: We split this sentence into two sentences: 'Under such conditions, a decrease of the asymmetry parameter leads to an increase of the Raman scattering probability, because more photons are scattered from the side into the line of sight. Such photons have a larger probability to be scattered on molecules.'

P737L3 "...of surface near aerosols,..."-> "...of near-surface aerosols..."

Corrected.

P738L15 "Both assumed stratospheric profile..." ->"Both assumed stratospheric pro-

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files..."

Corrected.

P738L20-21 "...compared to those of the surface near the aerosol scenarios,..." This is not a sentence.

Reply: We split the sentence into two sentences: 'The assumed stratospheric aerosol optical depth is rather small compared to those of the surface near the aerosol scenarios. Nevertheless, for large SZA systematic differences compared to the standard scenario are found (except for the radiance).'

Interactive comment on Atmos. Meas. Tech. Discuss., 2, 725, 2009.