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Atmospheric Measurement Techniques Discussions

Interactive comment on "Accounting for the effects of surface BRDF on satellite cloud and trace-gas retrievals: A new approach based on geometry-dependent Lambertian-equivalent reflectivity applied to OMI algorithms" *by* A. Vasilkov et al.

Anonymous Referee #1

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General

The topic of this paper is important for satellite retrieval of NO2 and other air pollutant gases. To precisely calculate the observed light path of trace gases, the inclusion of the bidirectional surface reflection has to be taken into account. Here it is proposed to sample the BRDF for the actual sun-satellite geometry to get a better estimate for the LER. The approach looks promising, and the results are interesting. After addressing the points below, the paper may be accepted.

The paper is well readable. However, at some points clarification is needed. A concern is the start of the introduction, which may lead to confusion. Furthermore, the interpretation of the results needs improvement. This is all indicated below.

Main points

(1) The start of the introduction, from l. 26 – l. 52 around Eqs. 1-3, seems detached from the remainder of the paper. The symbols and terms are different. The text and formulae are unclear. What is the link to the LER, which is used in the remainder of the paper?

- What is I(\omega) in Eq. 1? Is that the same as I_m in Eq. 4? What is the relation to the top-of-atmosphere radiance as observed by OMI ? Why do you use solid angle \omega, whereas in the remainder of the paper you use \theta and \phi? Why is F, mentioned below Eq. 1, not used in the equation? Explain \theta_r, which is called \theta in the remainder of the paper.

- In Eq. 2 please give the integration limits. Below Eq. 2 it is apparently assumed that this particular Lambertian has an albedo of 1. But also for a less reflective Lambertian surface the relation can be used.

- Eq. 3: does BRF in this equation yields Rg in Eq. 4?

(2) The interpretation of the scatter plots of retrieved cloud parameters from RRS and O2-O2 algorithms between the BRDF-dependent LER and climatology LER, especially the OCP, deserves more discussion. See Figs. 7 and 9. Apparently the RRS OCP is hardly depending on the surface BRDF, whereas the O2-O2 OCP is strongly depending on it. That is remarkable. It cannot be only explained by the decrease of Rayleigh scattering at 466 nm as compared to 354 nm, as stated in the paper. Another difference in both algorithms must be causing this. It is probably due to the fact that the RRS signal is not including all light paths that are relevant for the O2-O2 absorption (and NO2 absorption). Namely, the direct light path of direct sunlight reflected by the surface

and arriving at the satellite is not included in the RRS signal, because there is no Rayleigh (Raman) scattering involved. But it is an important light path for the cloud-free part of the pixel. And this direct light path is also strongly contributing to O2-O2 (and NO2) absorption. So the RRS method is in first order insensitive to the surface and to its BRDF. Only via the light paths Rayleigh + surface reflection, and surface reflection + Rayleigh can the RRS signal pick up surface BRDF effects. But that is a second-order effect. Please consider this cause in explaining the OCP behaviour of the RRS and O2-O2 algorithms.

(3) Please add histograms of ECF and OCP for the orbits shown, and not only scatter plots, to see the difference between including and excluding BRDF effects, and the difference between RRS and O2-O2 algorithms.

Questions and textual comments

- Eq. 4: please say that I_g and I_c are at top-of-atmosphere

- L. 67: is Ac=0.8 also assumed in this paper?

- L. 71: add here a reference to Stammes et al. (2008)

- L. 76: add here a reference to Sneep et al. (2008)

- L. 121: remove: its

- L. 141: does the RRS ECF hold for Rc=0.8 ?

- L. 175: please make a separate equation of the in-text formula.

- L. 185: please clarify: do you use in the paper the climatological ratio Rg(354)/Rg(470) or a ratio of unity?

- L. 208: please give a reference for MYD43GF.

- L. 215: I_TOA: why is a new symbol introduced? Where the other radiance symbols not at top-of-atmosphere? How does it relate to I_m of Eq. 4? Please do not intro-

duce unnecessarily new quantities and symbols. Please also relate \theta, \phi, and \theta_0 to the earlier introduced angles.

- L. 217 ff: the explanation of T is unclear. T is the total two-way transmission of the atmosphere.

- L. 245: Land is mostly darker in the UV than in the VIS. So why not use the climatological OMI data base at 354 nm?

- L. 265: please indicate the orbit and date.

- L. 300: is in Sect. 6 only the O2-O2 algorithm used and not the RRS algorithm because the latter has very little impact of BRDF?

- L. 301: why are the NO2 profile shapes from June and not from November, for which month the satellite data were chosen?

- L. 313: can you please explain how this formula is derived?

- L. 355: please mention here that the background aerosols are included in the climatological LER, but are missing in the BRDF, so that the ECF from the BRDF has a low bias.

- L. 366: the use > to use

- L. 385: missing: Chandrasekhar

Figures and captions:

Fig. 1: please use larger font for lat/lon (like in Fig. 2). What is the spatial resolution of these maps?

Fig. 2: please use a, b, c for the subplots. This also holds for the other figures with 3 subplots.

Fig. 4: which orbit and date? With which LER figure should this be compared? RRS-derived > RRS-retrieved

FIg. 5: which orbit and date?

Fig. 7: please write out the caption.

For Fig. 7 and Fig. 9 please consider inverting the axes, thus from 1000 to 0 hPa, because that looks more natural (low clouds at the origin of the plot).

Fig. 9: Please use better caption; the reference to the caption of Fig. 5 leads to another reference to another caption. What are the straight lines in the left plot?

Fig. 10: reflectivity > surface reflectivity

Fig. 11: which orbit and date?

Fig. 12: please number the subplots. Please add LER, OCP, fr to the legend of the lower 3 subplots.

Fig. 13: which date and orbit?

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