Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-37-RC3, 2019

Atmospheric Measurement Techniques Discussions
Open Access

Interactive comment on "Applying FP_ILM to the retrieval of geometry-dependent effective Lambertian equivalent reflectivity (GE_LER) to account for BRDF effects on UVN satellite measurements of trace gases, clouds and aerosols" *by* Diego G. Loyola et al.

Anonymous Referee #3

Received and published: 30 July 2019

Mateer et al. (1971) first proposed a Lambertian Equivalent Reflectivity (LER) concept in BUV total ozone retrievals to account for combined spectral dependence of surface, aerosols and cloud reflectance [Mateer, C. L.., D. F. Heath, A. J. Krueger: Estimation of Total Ozone from Satellite Measurements of Backscattered Ultraviolet Earth Radiance, J. Atmos. Sci., 28, 1307-1311, https://doi.org/10.1175/1520-0469(1971)028<1307:EOTOFS>2.0.CO;2, 1971]. The concept works well because ~90% ozone is in the stratosphere, above effective reflecting surface. The simple LER

Printer-friendly version

Discussion paper

concept with some modifications (e.g. extrapolated LER spectral dependence, effective surface pressure) has been successfully used in heritage (TOMS, GOME, SCIAMACHY) and current (GOME-2, OMI, OMPS, S5P/TROPOMI) stratospheric ozone and other trace gases (e.g., volcanic SO2) BUV retrievals.

The need for satellite retrievals of tropospheric ozone and other pollution gases (NO2, SO2, HCHO) in partly cloudy scenes, with peak concentrations in or just above the planetary boundary layer, required modification of the simple LER concept, replacing it with the mixed-LER (MLER) concept: mixing two LER surfaces, one at the ground and the other at the effective cloud pressure, e.g., [Ahmad, Z. et al: Spectral properties of backscattered UV radiation in cloudy atmospheres, J. Geophys. Res. Atmos., 109, D01201, https://doi.org/10.1029/2003JD003395, 2004; Stammes, P., et al.: Effective cloud fractions from the Ozone Monitoring Instrument: Theoretical framework and validation, J. Geophys. Res., 113, D16S38, https://doi.org/10.1029/2007JD008820, 2008]. The MLER approach is currently used in operational BUV pollution gas retrievals (e.g., [Levelt et al.: The Ozone Monitoring Instrument: overview of 14 years in space, Atmos. Chem. Phys., 18, 5699-5745, https://doi.org/10.5194/acp-18-5699-2018, 2018] and references therein). The MLER approach requires a-priori “clear-sky” LER estimate, which can be taken either from concurrent satellite measurements (e.g., OMI geometry-dependent GLER product uses higher-resolution atmospherically corrected MODIS BRDF [Vasilkov et al., AMT 2017]) or from prior measurements (e.g., OMI cloud-cleared climatological LER [Kleipool et al., JGR 2008]). The climatological “clear-sky” LER estimation is less accurate, since it disregards the observational geometry- and time-dependence of surface reflectance.

The paper by Loyola et al. presents new geometry-dependent (GE-LER) LER implementation, the "Full Physics – inverse Learning Machine (FP_ILM)" algorithm and the multiple day gridded LER product (G3_LER) derived from the present and previous clear-sky scenes observed by S5P/TROPOMI. In previous LER implementations for ozone retrievals, the LER values were derived at non-absorbing wavelengths (e.g., 340nm and 380nm for Nimbus-7 TOMS) and spectrally interpolated to the ozone and SO2 retrieval windows. The important advantage of the new GE-LER retrieval is that it is retrieved in the same spectral fitting window used by ozone retrieval (325-335nm), thus does not require spectral extrapolation. This is the first simultaneous retrieval of both ozone and LER in this spectral window. The G3_LER can be applied to existing S5P aerosol, clouds and trace gas algorithms by replacing climatological clear-sky LER with the new G3_LER product.

I recommend publishing the paper with clarifications and technical corrections and releasing the new S5P GE_LER and gridded G3_LER products for community evaluation.

General comments

1) The name "full physics" is misleading, because the forward radiative transfer model used for NN training does not include important physical processes, such as , aerosols and inelastic (RRS) scattering;

2) acknowledge that BRDF effects on trace gas retrievals cannot be modeled exactly using forward RTM with Lambertian surface. Estimate the ozone errors due to Lambertian surface assumption (GE_LER or simple LER) using BRDF supplement available in VLIDORT RTM.

3) Provide more details about GE_LER algorithm:

a. Do you assume that GE_LER is wavelength independent within DOAS fitting window?

b. Give reference to the machine learning (NN) software and explain selecting optimal NN topology used in the algorithm training.

c. Clarify whether the RTM with Lambertian surface or with BRDF model was used for training?

Printer-friendly version

Discussion paper

d. Explain which cloud masking algorithm was used in creating G3_LER clear-sky daily map

e. Fig. 1– clarify that “simulated features” are DOAS ozone slant columns and polynomial closure coefficients.

f. Fig. 2 – clarify that “extracted features” are DOAS ozone slant columns and polynomial closure coefficients.

4) Clarify what are effects of UV-absorbing aerosols (dust or smoke) on GE_LER?

5) Clarify that the neural network is trained on synthetic clear-sky spectra, but applied to the TROPKMI measurements over mixed, partly cloudy scenes (equation 5).

6) Compare TROPOMI GE_LER retrievals with the traditional LER retrievals at 340nm, where ozone absorption is negligible. Add TROPOMI simple LER340 map to Figure 10.

7) Publicly release G3_LER data set for community evaluation.

Technical comments

Table 2 is not mentioned in the text.

P1, 12: with a significant[ly] lower spatial resolution . . .

13: satellite viewing [geometry] dependencies

P2, 1: are mayor [major] error sources – clarify that the surface reflectance has larger influence on boundary layer trace gases retrievals and much less on the mid-and upper-tropospheric constituent retrievals.

13: significant[ly] lower spatial resolution

18: (b) the effect of surface reflectance anisotropy [is]

20: Retrieval of [Lambertian] effective scene albedo has been used in total ozone algorithms from nadir and limb – add pioneering reference: Mateer, C. L.., D. F. Heath, A. J. Krueger: Estimation of Total Ozone from Satellite Measurements of Backscattered Ultraviolet Earth Radiance, J. Atmos. Sci., 28, 1307-1311, https://doi.org/10.1175/1520-0469(1971)028<1307:EOTOFS>2.0.CO;2, 1971.

22: - add references to heritage TOMS ozone, e.g., Bhartia, P. K., et al.: Algorithm for the estimation of vertical ozone profiles from the backscattered ultraviolet technique, J. Geophys.Res., 101, 18793–718806, 1996 McPeters, et al.: Earth Probe Total Ozone Mapping Spectrometer (TOMS) Data Products User's Guide, NASA/TP-1998-206895, 1998.

- and OMI ozone references, e.g., McPeters, R. D., Frith, S., and Labow, G. J.: OMI total column ozone: extending the long-term data record, Atmos. Meas. Tech.,8, 4845–4850, https://doi.org/10.5194/amt-8-4845-2015, 2015.

Veefkind, J. P., et al.: Total ozone from the Ozone Monitoring Instrument (OMI) using the OMI-DOAS technique, IEEE T. Geosci. Remote, 44,1239–1244, 2006.

24: from other [higher spatial resolution] satellite sensors

28:" needed for computing LER from [and] BRDF may not be fully compatible" – need clarification: In Vasilkov et al., [2017] LER is calculated from the RT model simulated TOA radiance in a standard way, which is fully compatible with OMI cloud and NO2 retrievals. However, MODIS BRDF product may use different RT assumptions.

P3,

16: errors could be large and [multi-dimensional interpolations are] time consuming.

21: During the last years we [Recently] we developed an approached called . . .

22: applied for retrieving [ozone] profile shapes . . .

P4,

4, . . . the surface properties - clarify what properties? Did you use RTM with Lambertian surface for training or did you use RTM with BRDF model? Specify, which land/ocean BRDF model/dataset was used for training ?

15 resolution to resolve [absorbing] features

16 usually contains [hyperspectral] radiances at a high-dimensional space

17 . . .avoiding the effects of the curse of dimensionality ? – clarify

27 Explain where does the GE_LER information comes from (i.e., equation (3))?

P5, 19 . . . effective scene approximation - add reference ([Mateer et al., 1971;] Coldewey-Egbers et al., 2005)

21 whereas a [clear-sky] LER is needed

22 GE_LER retrieved under clear sky conditions – explain cloud masking algorithm

24, Fig 3 . . . based on the [GE_]LER data from previous days – Clarify if the GE-LER map instrument and viewing geometry specific?

25-26 (BRDF) effects, as it is based on radiative transfer model simulations using the actual viewing geometry – clarify did you use RTM with Lambertian or BRDF surface? What surface BRDF model/dataset (if any) was used in creating training spectral dataset?

P6,

2 fitting a polynomial of clear-sky LERs averaged as function of ðİIJČ . – Please, clarify: - should BRDF function also depend on solar and azimuthal angles in addition to satellite view angle?

- Provide examples (add figure) of the clear sky LER(theta) for land and water surfaces.

17 synthetic UV spectra – clarify that spectra were simulated assuming Lambertian surface, no aerosols and no inelastic RRS effects.

19 ozone [profile?] climatology

24 Figure 4 shows the optical densities difference – clarify definition of the optical density and the OD difference. Explain why is Figure 4 necessary?

25 ... albedo of 0.05, 0.3, 0.6, and 0.9 [,which] correspond to water,.. – not clear how [ozone?] optical density is related to the surface albedo?

28 higher [longer?] wavelength.

P7,

1, Fig 4 . . . optical density increases when the viewing zenith angle decreases – please, explain. The ozone optical density is proportional to the slant column ozone amount, which should decrease when the viewing zenith angle decreases. . . .for all cases, the optical density increases along the wavelength region –Explain why is this important?

3 . . .is reorganized according to (3) – clarify the meaning of equation (3) an re-organization algorithm

5 . . . using a NN with a topology of 9-20-8-2-1, - provide reference to the NN software used and how the optimal topology has been selected?

10, Fig.5 . . .represents the inverse function [of the synthetic dataset] in a very precise way – this does not guarantee similar accuracy when applied to the real satellite measurements.

Figure 6(a) title and color bar show "E_LER" – change to GE_LER

Figure 6(b) – explain cloud fraction stripes over Antarctica?

20 In the case of clear-sky (ðİŚŞðİŚŘ $\leq$ 0.05) the GE_LER represents the surface albedo – clarify if GE_LER represents hemispherical albedo or directional BRF ?

25 the TROPOMI clear-sky GE_LER and OMI LER climatology – Add comparison with the OMI/TROPOMI simple LER at 340nm in Table 2.

26 summarized in Figure 7. - in Table 2? P8,

1 . . . aggregating normalized [GE_]LER from the couple of days. – these retrievals are obtained under different viewing geometries. - Couple of days may not be sufficient to obtain cloud-free observations over certain locations. - Explain how GE_LER are normalized and what viewing geometry does the aggregated G3_LER map correspond to?

10 . . . averaged as function of the viewing zenith angle. – BRDF depends also on solar zenith and relative solar azimuthal angles. Why is this dependence ignored?

Fig. 8 Why is sun-glint is not visible for the water surface GE_LER and “hot spot” is not visible for the land GE_LER ?

What would GE_LER look like for a cloud-free sun-glint region?

Fig. 9(a) – what viewing geometry does the aggregated G3_LER map corresponds to? Reduce upper scale or use logarithmic scale to better show LER variability for snow-free regions. Clarify wavelength for the OMI climatological LER.

Fig 9 caption: the ma[j]or differences

Fig 10. Add comparison with the TROPOMI simple LER map at 340nm (negligible ozone absorption)

25 associated to [with] the coarse resolution

26 most important[ly]

p9,

5 what is even wors[e]

11 reduced from $-2.53 \pm 2.46\%$ using OMI LER to $0.78 \pm 3.49\%$ using TROPOMI G3_LER - why did the standard deviation increase?

P12,

11 Loyola, D., et al.: The near-real-time total ozone retrieval algorithm from TROPOMI onboard Sentinel-5 Precursor, Atmos.Meas. Tech. Discuss., in preparation, 2019. – provide complete citation

---

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-37, 2019.