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Atmospheric Measurement Techniques Discussions

Interactive comment on "MICRU background map and effective cloud fraction algorithms designed for UV/vis satellite instruments with large viewing angles" *by* Holger Sihler et al.

Anonymous Referee #1

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Summary:

Section 1 introduces a basic motivation and explains why cloud fraction retrievals are an important ingredient to trace-gas retrievals. It further provides an overview of existing algorithms and their respective heritage. A particular importance is rightfully directed to surface contributions and to the recent developments in the field to address BRDF effects. Instrument characteristics and the cumbersome relations between MSC and PMD read-outs are well explained (section 2.1). All used auxiliary data are briefly introduced and their treatment (spatio-temporal interpolation) is justified. The main part deals with the determination of the lower threshold T_min (section 2.3). The re-

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sult for the presented approach of a surface fit is shown for two example geolocations (Australia, Atlantic) at two different wavelengths (382 nm and 516.7 nm), respectively. Finally, the data sets where MICRU is compared against are briefly described (section 2.6). Section 3 shows results of MICRU for three example scenes of GOME-2 (Brazil, North America, Indian Ocean) and compares those to different FRESCO versions and OCRA. The various MICRU versions (MSC, PMD, different wavelengths) are also inter-compared to highlight their differences. The comparison to FRESCO and OCRA is also extended to monthly statistics and the temporal evolution is investigated. An interpretation of the comparisons and findings for several selected individual cases and larger statistics is presented in section 4, both for the various MICRU applications and also for the comparison algorithms. Section 5 reminds that the main topic of investigation are small cloud fraction regions and recalls the novelty approach of an empirical BRDF surface model. It concludes a transferability of MICRU to other spectroscopic satellite missions and imager data. It is finally recommended to prefer the UV/blue spectral region over the red spectral region to reduce surface effects. Finally, Appendices A to E provide further valuable information for the reader.

As an overall conclusion, the manuscript is well written and structured, provides a relevant and very interesting contribution to the scientific topic addressed and therefore I recommend its publication after the general comments are addressed.

general comments:

GC1): While a lot of effort is put into the investigation and determination of the lower threshold, the description and assumptions of the upper threshold are quite brief. The authors may consider to expand a bit on the justification of the chosen simplified approach for the upper threshold and for which types of clouds it may be justified and for which not.

GC2): Since many cloud retrieval algorithms struggle particularly over very bright surfaces, has the MICRU performance also been tested e.g. over snow/ice conditions?

Also the behavior over different strong aerosol events (desert dust, urban pollution etc.) could be interesting to analyze.

GC3): The consequences of using a fixed cloud albedo of 0.8 (p2, l30; section 2.4, etc.) should be discussed in more detail in the paper. For example, how should the trace gas retrieval use a MICRU CF>1 (p19, l8)? Are the MICRU CF applicable only to tropospheric trace gas retrievals?

GC4): A direct comparison between MICRU CF and FRESCO CF is possible because both algorithms use a fixed cloud albedo of 0.8. OCRA doesn't have this constraint, therefore the comparison between MICRU and OCRA (Section 3.2, 3.4.1., 3.4.3, 4.2, Fig. 11, Fig. 16, Fig. 17, Fig. 21 Appendix D,Appendix D, Fig. D1, Fig. D2, Fig. E5) should be extended by adding an additional 'OCRA CF_fixed_albedo' by converting the OCRA CF to a magnitude similar to the MICRU CF using the following approximation:

OCRA_CF * ROCINN_CA $\sim$ MICRU_CF * 0.8

OCRA_CF_fixed_albedo = OCRA_CF * ROCINN_CA/0.8

where ROCINN_CA is the cloud albedo retrieved with ROCINN. This adaptation can only be done at the MSC level because the ROCINN parameters are only provided for the MSC footprints and not at PMD level, hence for the OCRA PMD cloud fraction, this modification cannot be applied. However, the manuscript focuses on providing accurate cloud information for the retrieval of trace gases. Since the trace gases are retrieved for the MSC data, I would strongly suggest to add to the comparisons also the OCRA cloud fraction for the MSC data including the adaptation with the ROCINN cloud albedo as outlined above. In summary, I would recommend to

a) add to the comparisons also the "OCRA_CF_fixed_albedo" for the MSC data as outlined above, and

b) add to the conclusions for the OCRA PMD vs MICRU PMD comparisons a statement that the modification with the cloud albedo as outlined above cannot be done at PMD

level and this might be a potential source for discrepancies in the comparison.

Further specific comments and technical corrections below refer to p(age) and l(ine) of manuscript amt-2020-182.pdf:

specific comments:

p3, l4: There are also new retrieval algorithms that combine the LER models with a geometry-dependent BRDF correction, see for example (Loyola et al., 2020) https://doi.org/10.5194/amt-13-985-2020

p3, l32: p5, l1; and p22, l11: The third version of OCRA was not applied to TROPOMI but to OMI. The fourth version of OCRA (Loyola et al., 2018) https://doi.org/10.5194/amt-11-409-2018 is applied to TROPOMI, but this reference is missing in all three paragraphs.

p4, l34: To be more precise, for the TROPOMI/S5-P mission OCRA is part of the S5P L2 CLOUD product and FRESCO is an auxiliary cloud product used for the S5P L2 NO2, ALH, CH4 and O3 profile products.

p6, l23: Could you specify, which data version was acquired from EUMETSAT? Was it the reprocessed AC-SAF data set?

p10, Figure 4: The last sentence of the figure caption might be confusing and binning #1 might be misunderstood as native resolution. Please rephrase to avoid confusion.

p10, l5: Forward and backward scans were not mentioned before. A short introduction and explanation, why backward scans are discarded could be beneficial for the reader here.

p15, caption of Figure 7: In addition to observation geometry and wind speed, doesn't the sun glitter contribution also depend on geolocation and time? E.g. in summer the sun glitter appears at different latitudes than in winter. Please clarify.

p15, l8: Same reference is given twice: "...swath edge in Figs. 8(d,e) and 8(d,e)"

p15, l9-13: Additional tests are described but discarded because of inferior results in a number of case studies. In my opinion it could be elaborated a bit more on the reasoning of selecting these choices in order to give the reader a bit more background information.

p16, table 5: Why is degradation for MSC channels 12, 13, 14 constrained to 0? Please add short explanation.

p17, Figure 8(b): Is there a mixup, where in the text "... measurement set Omega_0 (red) and finally fitted set Omega_I (blue)", the colors red and blue should be swapped? The figure legend says that the fitted data are the red points.

Figures 8e and 9e: The surface fits for MSC 2 over Australia (8e) and MSC 10 over Atlantic (9e) show very different patterns. The former is strongly pronounced in the western half of the swath and becomes stronger in time while the latter is restricted to the east half of the swath and present for all years 2007-2013. Is there a simple explanation for the driving factor behind these differences (except geolocation and wavelength)? Edit: Ok, the pattern of the latter is later addressed on p24, l30 and assigned to sun glitter but what could be the explanation for the increasing trend in the first example?

p19, l8: How are MICRU CFs > 1 treated? Are they cropped to 1 or flagged? Please clarify.

p19, section2.4: The upper threshold is assumed to be fixed with a cloud albedo of 0.8 at an altitude of 7km without a dependency on geolocation and time. While a lot of effort has been put into the various dependencies for the lower threshold, the assumptions on the upper threshold are few. It is argued that MICRU focuses on small CFs, but how valid is e.g. the assumption of cloud albedo = 0.8 in the case of an optically very thin cloud close to the surface or very high in the troposphere? Could it be specified for which type of clouds this simplified assumption on the upper threshold is valid and justified and for which not?

p21, l24: The sentence “probably the most commonly used CF product” is not correct. Most of the operational GOME-2 AC-SAF trace gas products are based on the OCRA/ROCINN algorithm.

p22, l14: “and OCRA applies a volumetric (or scattering) cloud model”. Technically, the scattering cloud model is only relevant for the ROCINN part of the OCRA/ROCINN algorithm combination, which retrieves cloud top height and cloud optical thickness. For the OCRA cloud fraction using the color space approach, the relevant assumption is a spectral independence of a fully cloudy reflectance across the UV/VIS wavelength range. Therefore, “and OCRA applies a color space approach for the upper threshold (Lutz et al., 2016)” seems more fitting.

p23, l1-2: The sentence “These biases propagate into trace gas retrievals if normalized CF data are applied” may apply to FRESCO but is not correct for OCRA/ROCINN. Any possible bias on the OCRA CF will be compensated in the ROCINN cloud albedo and therefore possible bias will be not propagated into trace gas retrievals (Loyola et al., 2007) http://dx.doi.org/10.1109/TGRS.2007.901043

p31, Figure 16: Title and axis labels say “PMD ch 1” and “PMD-PP cloud fraction @ 382 nm” while the figure caption reads “MICRU MSC at 440 nm”. Please clarify.

p31, l7: see comment to p22, l14

p37, Figure 21: Is there a reason that subplot (a) shows all three FRESCO versions L1b , v7 and v8 while in subplot (b) only the FRESCO v8 are shown?

p37, Figure 21: Are sun glitter scenes included in the 15th percentile cloud fractions shown? The difference for the OCRA East might be due to the fact that sun glitter appears only in the east half of the swath and OCRA sets scenes affected by sun glitter to zero by default. This might contribute to the low bias.

p38, l19-20: Please note that the VZA dependence in OCRA is also evaluated empirically with a monthly temporal resolution.

p40, l13-15: It is true that the OCRA sun glitter removal at areas with larger theta_r may be positively biased (particularly visible in the left swath of Figure 11(u)). However, it could also be pointed out here that in regions of very strong sun glitter (yellow in Figure 11(c)), OCRA seems to properly account for this effect (visible in the right swath of Figure 11(u)). Furthermore, OCRA includes a sun glint flag.

p45, l6: This is a very interesting detail. Could this terrestrial sun glitter signal over the Amazonas be related to high oriented ice crystals as suggested by Marshak et al. based on EPIC/DSCOVR? (Terrestrial glint seen from deep space: Oriented ice crystals detected from the Lagrangian point https://doi.org/10.1002/2017GL073248)

technical corrections:

p2, l25: change “the time dependent the” to “the time dependency of the”

p2, l28: change “a-priory” to “a-priori”

p2, l30: change “albedo of 0.8 Stammes et al. (2008) rendering” to “albedo of 0.8 as in Stammes et al. (2008), rendering”

p7, l16: change “channels 2,5, 10” to “channels 2, 5, 10” (blank space missing before 5)

p16, l21: change “a-priory” to “a-priori”

p20, l1: change “to form a complete parametrisations” to “to form complete parametrisations”

p20, l17: change “prior the T_min retrieval” to “prior to the T_min retrieval”

p22, l4: something is missing in “is increased to effects of”. Maybe “is increased to cover effects of”?

p22, l15: Sentence “Some FRESCO both and OCRA. . .” sounds weird. Is the following meant: “Both FRESCO and OCRA. . .”?

p24, l17: change “in discrete boxed defined” to “in discrete boxes defined”

p29, l5: change “evaluation” to “evaluations”

p29, l6: change “and m = 1 519nm” to “and m = 1 at 519nm”

p31, l6: change “differently” to “different”

p32, l19: “Figs. 19(d) and (g))”: Shouldn’t this be “Figs. 19(c) and (f)”?

p37, caption of Figure 21: first line ends with “(b): comparison between selected MICRU”, while it should be “(a): comparison between selected MICRU”.

p38, l32: change “retried” to “retrieved”

p40, l5: “(Fig. 21(c))”: Fig. 21 has no subplot (c). Is Fig. 21(b) meant?

p40, l24: “at coasts an inland”: Is “at coasts and inland” meant?

p40, l30: “as investigated by Fig. 19).” The closing bracket has no opening bracket.

p48, caption of Figure D2: “circled values in (c)”: The circles are in (a)

p49, l5: at the end of line change “onky” to “only”

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