Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-128-RC1, 2017
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Atmospheric Measurement Techniques
Discussions

Interactive comment on "The operational cloud retrieval algorithms from TROPOMI on board Sentinel-5 Precursor" *by* Diego G. Loyola et al.

Anonymous Referee #2

Received and published: 30 June 2017

Review of the manuscript by Loyola et al.

The manuscript describes the OCRA cloud fraction and ROCINN cloud pressure algorithms and their modifications that were made to adapt the algorithms for TROPOMI. Most material of the manuscript has been published. However, the paper contains some original material that is mainly related to the modification of the ROCINN algorithm. This material may be of interest for the developers of cloud algorithms for satellite hyperspectral radiometers. Moreover, the OCRA and ROCINN cloud algorithms were selected for TROPOMI; that is why it is important to document the algorithms in the literature. The paper subject is appropriate to AMT. Earlier work is recognized and credited. The abstract provides a sufficiently complete summary of the paper. The paper is well organized. I think that the paper needs significant revisions before rec-

ommending it for publication. The authors should address the following comments.

General comments

1. The authors state that the cloud pressure algorithm, ROCINN_CAL, provides better cloud-top retrievals than ROCINN_CRB. The TROPOMI cloud products are intended to use in trace-gas retrievals. It is not obvious that the cloud-top pressures can produce better trace-gas retrievals. The Mixed Lambertian Equivalent Reflectivity (MLER) model compensates for photon transport within a cloud by placing the Lambertian surface somewhere in the middle of the cloud instead of at the top. As clouds are vertically inhomogeneous, the pressure of this surface does not necessarily correspond to the geometrical center of the cloud, but rather to the so-called optical centroid pressure (OCP). Cloud OCPs are the appropriate quantity for use in trace-gas retrievals from satellite instruments. Cloud-top pressures are not equivalent to OCPs and do not provide good estimates of solar photon path lengths through clouds that are needed for trace-gas retrievals from ultraviolet and visible wavelength solar backscatter measurements (Ziemke et al., 2009; Joiner et al., 2012). The authors should prove that the ROCINN_CAL cloud-top pressures do produce better trace-gas (e.g. O_3 or NO_2) retrievals. That is particularly important in the view that the TROPOMI NO_2 algorithm makes use of OCPs from the MLER-based FRESCO+ cloud algorithm (van Geffen et al., TROPOMI ATBD of the total and tropospheric NO_2 data products, URL: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-5p-tropomi/document-library, 2016).

J.R. Ziemke, J. Joiner, S. Chandra, P.K. Bhartia, A. Vasilkov, D.P. Haffner, K. Yang, M.R. Schoeberl, L. Froidevaux, and P.F. Levelt, Ozone mixing ratios inside tropical deep convective clouds from OMI satellite measurements, Atmos. Chem. Phys., 9, 573-583, 2009.

2. The OCRA algorithm has been described in detail in Loyola et al. (2007) and Lutz et al. (2016). In those papers, the authors used the normalized RGB (red-green-blue)

representation of colors. In this manuscript the authors propose the Green-Blue color system for TROPOMI. This switching to the GB system should be explained because the red channel (675-775 nm) is available in TROPOMI. The authors should also compare cloud fraction retrievals from RGB and GB using e.g. GOME-2 data.

3. The use of the Mie scattering model of clouds is new in the ROCINN algorithm. That is why it is important to show that the selection of a single water cloud model, i.e. a single phase scattering function, is representative. Clouds can be multilayer and vertically-extended. This significantly affects photon path lengths and thus oxygen absorption in the cloud. The authors should show that their selection of a vertically-uniform cloud model with a single geometrical thickness of 1 km is sufficiently representative. The authors should provide an estimate of possible cloud pressure errors associated with the selection of the cloud model.

4. The authors should add a couple of paragraphs describing how their radiometric cloud fraction is used in the DOAS trace-gas algorithms. It is important to highlight the differences between the use of the radiometric cloud fraction and effective cloud fraction that comes from the MLER model.

5. The authors show a comparison of the OCRA radiometric cloud fraction with the MODIS geometrical cloud fraction. It is unclear why the authors do not carry out a similar comparison of the ROCINN_CAL cloud-top pressure with the MODIS cloud-top pressure. This comparison should be done and quantitative results of the comparison should be provided.

Specific comments:

Abstract. Some numbers characterizing the error budgets are strongly recommended in the abstract.

Introduction. Please add the following reference and discuss how your approach differs from that by Diedenhoven et al. (2007)

Diedenhoven et al., Retrieval of cloud parameters from satellite-based reflectance measurements in the ultraviolet and the oxygen A-band, JGR, 112, D15208, doi:10.1029/2006JD008155, 2007.

P.4, L.13. "the minimum Lambertian equivalent" should be "the mixed Lambertian equivalent"

P.4, L.17. "in the range 330-390 nm" is incorrect; OMAERUV makes use of just two wavelengths 354 and 388 nm.

P.5, L.27. Is it correct that the scaling and offset factors are determined using daily satellite measurements, not monthly?

P.6, L.5. "a simplified sun-glint correction". Do you mean "sun-glint flagging"? Please provide information about the performance of the cloud algorithms over the sun glint area. For instance, this information can include the cross-track dependence of daily-averaged OMI cloud fraction and cloud pressure for such areas.

P.8, L.21-22. Your statement about small effect of the cloud phase (water or ice) should be proven by radiative transfer simulations. Please provide comparisons of computed TOA radiances for water and ice clouds and corresponding cloud pressure errors.

Section 4.4. Please provide information about a number of computational nodes over surface reflectance, surface altitude, solar and viewing angles.

P.9, L.11-12. Please provide typical errors of replacing exact radiative transfer simulations by neural network calculations for different sun-view geometries.

P.10, L.2-3. "the surface albedo climatology"; please provide a reference

P.10, L.4. "only very small changes are allowed" is a qualitative statement. Please provide quantitative information.

Section 4.6. describes well known theoretical estimates of the DFS and retrieval errors. Why the numerical estimates are not used in the text? I would remove this section and retain just a reference.

Section 5. Most statements in this section are qualitative like “can be accurately retrieved” (L.18), “quite sensitive to”, “less significant are ROCINN errors” (L.20). The section titled “Error characterization” should provide quantitative information.

P.11, L.19. Do you really mean “cloud geometrical fraction”, not radiometric?

P.12, L.4. Why the NIR stray light effects “will be assessed when the instrument provides measurements from space”? You say that “stray light issues were identified in the NIR band”. The stray light contribution can be important for most absorption lines of the oxygen A-band. The authors should assess the stray light effects on the retrieved cloud properties. It seems to be straightforward to simulate stray light and investigate the impact on cloud pressure retrievals.

P.13, L.21-22. “This OMI cloud fraction is based on the filling-in of solar Fraunhofer lines caused by Raman scattering” is incorrect. The OMCLDRR cloud fraction is derived at 354 nm where the Raman scattering contribution is minimal.

P.13, L.27. Please explain why “the UV sensors are not sensitive to optically thick clouds”. What physics do you mean in this statement?

P.14, L.2-3. Please explain the meaning of “OCRA and OMAERUV report cloud fraction values more representative of the radiometric cloud fraction measured by the instrument”. The instrument measures TOA radiances.

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