

## ***Interactive comment on “Validation of the Sentinel-5 Precursor TROPOMI cloud data with Cloudnet, Aura OMI O<sub>2</sub>-O<sub>2</sub>, MODIS and Suomi-NPP VIIRS” by Steven Compernelle et al.***

### **Anonymous Referee #1**

Received and published: 29 July 2020

This paper presents an evaluation of cloud products retrieved using the Sentinel-5 Precursor TROPOMI instrument. Cloud properties from the Cloudnet, Aura OMI O<sub>2</sub>-O<sub>2</sub>, MODIS and Suomi-NPP VIIRS datasets are used for this evaluation. The TROPOMI cloud products are mainly used to correct of filter trace gas retrievals that are performed with TROPOMI, but it is useful to evaluate the products with more established datasets. The paper is of interest for AMTD.

The paper is generally well written and structured, although information is somewhat scattered. I recommend publication after the general and specific comments listed below are addressed.

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#### General comments:

1) The different algorithms and datasets are described throughout the paper. Information is somewhat scattered through the introduction, section 2 and section 3. Also, some information is given for one algorithm but not for others. I suggest merging this information in a more consistent manner in a single section. For example, quite specific information on the FRESCO algorithm on the adjustment of the spectral resolution of the database is in the introduction, but is better placed in a section, while it also raises the question how/if these wavelengths shifts are handled in the OCRA/ROCINN.

2) A distinction is made between the radiative cloud fraction (RCF) and the scaled RCF (sRCF). However, the RCF should be better defined in the paper. If I understand correctly, the RCF generally is the cloud fraction that leads to the observed reflectance under the assumption of a certain cloud reflection. If the assumed cloud reflection is the correct one then the RCF is equal to the geometric cloud fraction. For FRESCO it is clear what the assumed cloud reflection is (0.8), but it is less clear for OCRA/ROCINN. From the literature I get the impression that OCRA/ROCINN is capable of determining whether a pixel is fully cloudy ('white') or not. But for fractional clouds, I suspect it is biased towards assuming a high cloud reflectance similar to FRESCO. That is also supported by the RCF in Figure 5 being very similar to the sRFC in Fig 6, which are both similarly low-biased compared to VIIRS cloud fraction. The histograms in Fig. 8 are filtered to have "only pixels with a VIIRS geometrical cloud fraction, which originates from a cloud mask, above 0.9 contributed to the comparison." Although this sentence is unclear (see specific comments), my interpretation is that any TROPOMI pixel is included if it is 90% covered by cloud as determined by VIIRS. As mentioned above, these are situations where OCRA/ROCINN is probably doing a reasonable job on identifying a high cloud fraction and retrieving the cloud optical thickness. It masks the performance of determining cloud optical depths for low cloud fractions. Please discuss the interpretation of the retrieved RCF and optical thickness for cases with fractional cloud cover. A 2D histogram of retrieved cloud optical thickness (or albedo)

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and radiometric cloud fraction of all the OCRA/ROCINN results would be helpful.

Specific comments:

Page 2, line 5: Remove the extra periods after "(SO<sub>2</sub>)". Page 2, line 27-28: The two references are both relevant for using the PMDs but no reference for using the UV spectral measurements is given. A suggestion is "Van Diedenhoven, B., O.P. Hasekamp, and J. Landgraf, 2007: Retrieval of cloud parameters from satellite-based reflectance measurements in the ultraviolet and the oxygen A-band. *J. Geophys. Res.*, 112, D15208, doi:10.1029/2006JD008155."

Equation 1: In the statement about "if  $f_c=0$ ", I guess that should be "if  $f_{rc}=0$ ", but this follows from the main equation so seems not needed.

Equation 2: The other algorithms are using O<sub>2</sub> absorption lines and thus are also expected to retrieve cloud (top) pressure instead of height. I guess the conversion represented by Eq. 2 is already done in these products. Please discuss in the paper.

Page 9, line 11-13: The sentence starting with "For scenes with clouds" is very fragmented and hard to follow. I suggest rewriting.

Page 10, line 27-31: I am a bit confused what is meant with "pixel" in these sentences. Do you mean "altitude bin" or "range gate" of the radar/lidar measurements or collocated satellite pixel. I suggest rewriting to make this clearer.

Page 17, line 16-17: It is stated that "only pixels with a VIIRS geometrical cloud fraction, which originates from a cloud mask, above 0.9 contributed to the comparison". Are the pixels in this sentence TROPOMI pixels? That is, are only (near) fully cloud covered TROPOMI pixels included? Although the reason given is to reduce artifacts, it is quite a limitation of the comparisons as the performance of OCRA/ROCINN to retrieve optical thickness and height for fractional cloud cover is not evaluated.

Page 17, line 25: An effective COT is introduced. Please make sure to identify where this effective COT is used. Are the histograms in Fig 9 showing the effective COT from

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TROPOMI? If so, I think that important detail is easily missed (If so, it was by me.). If so, how does Fig. 9 look like without that scaling? Also, I would think that this scaling might work with an albedo, but not with COT, since reflectance scales highly non-linear with COT. Please discuss in the paper.

Page 17, lines 28-30: Please check the wavelengths mentioned here. VIIRS does not have a 2.16 micron band, so I am quite sure that should be 2.25 micron. Also, I would think the optical thickness is inferred from 0.67 micron over land and 0.86 over ocean.

Page 19, line 8: "Aggregated" should be "aggregates".

Page 19, line 22: Looking at table S2, I notice that the mean CTH determined by TROPOMI for high clouds is often lower than the threshold for high clouds. I guess the classification is done using the VIIRS cloud properties only. If so, please state this in the paper or otherwise explain. I also suggest moving table S1 in the main text.

Page 21, Fig 9: This is a very complicated and busy figure. I had some trouble understanding what the x-axis represents, so please explain this better. I still do not understand how the CLOUDNET classes are represented with the pink, white and blue colors. I think a bit more text explaining all the different and dots would be helpful.

Page 23, line 14: What are "zero offset clouds"?

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Interactive comment on *Atmos. Meas. Tech. Discuss.*, doi:10.5194/amt-2020-122, 2020.

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