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“OCRA radiometric cloud fractions for GOME-2 on MetOp-A/B” by R. Lutz et al.

http://www.atmos-meas-tech-discuss.net/amt-2015-363/

This document provides the author's responses to the comments of anonymous referee #1 regarding the manuscript quoted above.

Comments from Anonymous Referee #1:
RC C4664: 'referee comment', Anonymous Referee #1, 05 Jan 2016

Throughout this document, the following scheme is applied to discriminate between referee comments, author's responses and author's changes in the manuscript:

italic font: *comments from referees*
normal font: author's response
red font: author's changes in manuscript

NOTE: Due to the suggested re-structuring of the manuscript, some Figures now have different numbers in the updated manuscript: The affected Figure numbers (old number → new number) are:
old 20 → new 21,
old 21 → new 22,
old 22 → new 23,
old 23 → new 24,
old 24 → new 25,
old 25 → new 20.
Figure numbers 26, 27 and 28 are new in the updated manuscript.

NOTE: In the marked-up pdf manuscript version with tracked changes created with latexdiff in LaTeX, somehow the section label 4.1 is counted twice. This mis-labeling however does only appear for the tracked version with latexdiff but not for the normal version created with LaTeX.

Anonymous referee #1 General comments:

The authors have presented the OCRA algorithm and the degradation correction of the GOME-2 A/B PMD data in detail. It is an interesting paper. I think the paper fits the scope of AMT. The comparison of OCRA radiometric cloud fraction and AVHRR geometric cloud fraction is very helpful for users to understand the OCRA cloud product. However, the authors have not given enough explanations about the theoretical back ground (physics) of the OCRA algorithm. It would be more convincing if the authors could perform some radiative transfer model simulations for the OCRA algorithm. For example, simulate the reflectances of the RGB PMDs for cloudy cases over different surface types, then apply the OCRA algorithm to derive the radiometric cloud fractions. From the simulations, users will know exactly what to expect from the OCRA radiometric cloud fraction. I think a clear explanation of the concept of the OCRA radiometric cloud fraction is also missing in the paper although it is defined in Eqs. 6-8. This simulation can also contribute to the understanding of the white point [1/3, 1/3]. Is it exactly [1/3, 1/3] in reality?

As suggested by the reviewer, simulations of cloudy scenes have been performed. Based on these simulated OCRA RGB reflectances, a normalized rg-color diagram has been generated (new Figure 27), which clearly shows that the fully cloudy scenes slightly scatter around the theoretical white point at [1/3, 1/3]. See also reply to specific comment #1).

A new Figure (Figure 27) has been included in the manuscript. A corresponding paragraph has been added to the "Discussion" section.

The GOME-2 L1 data include an effective cloud fraction product derived from the O2A band. This effective cloud fraction has been used in trace gas retrievals for cloud screening or cloud correction (together with cloud height). The paper would be more complete if the authors could compare the OCRA radiometric cloud fraction with the GOME-2 L1 effective cloud fraction.

The GOME-2 L1 effective cloud fraction (FRESCO) is given only for the 80km x 40km ground pixels but not for the 10km x 40km PMD footprints. However, a mapping of the OCRA PMD cloud fraction and the L1 FRESCO effective cloud fraction to a common grid with one degree resolution has been performed in order to do a comparison. For this comparison, also the AVHRR cloud fractions from the PMAp product are included. See new Figure 26. See also reply to #8).

A new Figure (Figure 26) has been included in the manuscript showing a comparison between the OCRA, FRESCO and AVHRR cloud fractions. Detailed explanations are also added to the manuscript.

Anonymous referee #1 Specific comments:

1) P13475, lines 5-10
Could you simulate the reflectances of the RGB PMDs? As shown in Fig. 14, the reflectances of R and G are not the same for fully cloudy scenes, otherwise the Pr and Pg should be equal to 1/3. What are the reasons for the difference?

The assumption that the white point in the normalized rg-color diagram is exactly at (1/3,1/3) implies that the colors R, G and B are exactly the same, i.e. R=B=G. Measured and simulated spectra of fully cloudy scenes show that R, G, and B are very close to each other, but not exactly the same. These small deviations result in a small shift of the fully cloudy scenes from the theoretical white point. See also reply to the first general comment of Referee #1).

A new Figure (Figure 27) has been included in the manuscript. A corresponding paragraph has been added to the "Discussion" section.

2) p13476 lines: 19-24
Why PMDs 2-14 are used in the definition of the RGB colors? In principle it is possible to use 3 PMDs to make a RGB image. There are ozone, water vapor and O2 absorption in the PMD wavelength bands. Will the gas absorptions influence the determination of the cloud free points?

The PMDs 2-14 are used to match the wavelength ranges of the PMDs from the GOME-1 instrument. In order to avoid the strongest ozone absorption features, the PMDs 0,1 and 2 of GOME-2 have been excluded. Since the used wavelength ranges are very broad and since we also use the median, we assume the influence of mentioned absorption features on the cloud-free determination to be negligible.

Are there any advantages to use both PMD P and S polarization to determine the radiometric cloud fraction? Fig. 25 shows the differences of P and S based radiometric cloud fractions, they are quite small even over snow/ice.

Although being quite small, Figure 25 shows that there are systematic differences over snow/ice and we think that this is worth to be investigated further in future work. In the operational environment we use both PMD P and S.

3) Fig. 11 cloud-free maps
Are the cloud-free reflectance maps actually derived from the minimum reflectances of the PMDs? In the GOME-2 LER surface albedo product, there are minimum LER albedo and mode LER albedo. The large differences between the mode and minimum surface albedo are over deserts and sea ice. Is it possible to introduce a bias if using the largest distance of the measurements to the [1/3, 1/3] point to determine the cloud-free cases?

The cloud-free reflectance maps are derived from the minimum PMD measurements in the RGB color space, in other words, the minimum is calculated in the 3-D vector space. In order to minimize the possibility to introduce biases over the mentioned regions, we investigate the implementation of surface dependent scaling factors (see response to next point).

4) Fig.12
In some months the cloud-free reflectances for the alpes abd Hudson Bay surface types are very close

to the [1/3, 1/3] point. Will this cause mis-identification of cloudy scenes?

Yes, in these cases the cloud fraction may be under-estimated when the actual snow/ice conditions are quite different from the climatology cloud-free conditions. As mentioned in section 4, the implementation of surface dependent scaling factors is being considered for future work. Tests with OMI data are very promising and an adaptation to GOME-2 is also foreseen for future versions of the OCRA algorithm.

5) 2.5.2 Eqs. 6-8
Could you explain why the OCRA cloud fraction is an radiometric cloud fraction? Why the cumulative histogram value of 0.99 is used to determine alpha? Does it suggest that a very bright cloudy scene has a radiometric cloud fraction of 1? What is the physical meaning of the beta? Should beta be 0 in an ideal situation? Have you tried to use Eq. 5 to determine a geometric cloud fraction? The distance from the measurement to the white point is part of the distance between the cloud-free point and the white point, which could be linked to the geometric cloud fraction.

The resolution of the GOME-2 PMD footprints is too coarse to resolve individual clouds. In the context of the independent pixel approximation, the pixel reflectance can be expressed as the sum of the reflectances of the true cloudy part (i.e. geometrical cloud fraction) and the cloud-free part. Since these parts cannot be clearly separated given the PMD footprint resolution, OCRA computes a radiometric cloud fraction instead of a geometric one. The cumulative histogram value of 0.99 has been chosen in order to be robust against outliers caused by instrument artifacts or extremely bright events (the 1% of measurements with the highest rho_measured minus rho_cloudfree are excluded in the determination of the scaling factor). Tests have also been conducted with values of 0.9, 0.999 and 0.9999. Finally, the 99% value has been chosen and fixed for all colors in order to secure a consistent treatment. The beta offset accounts for aerosol and similar radiative effects on the atmosphere; as correctly suggested by the reviewer, beta will be 0 under ideal conditions.

6) Table 3
Why the alpha and beta values are different for P and S pol for GOME-2B but quite similar for GOME-2A?

That is a very good question. We think that GOME-2A PMDs are better calibrated/characterized than the ones from GOME-2B.

7) Fig. 14
In the derivation of the cloud-free map, Eq. 5, the white point is assumed to be fully cloudy. In Fig. 14, for the cloud fractions close to 1.0, the Pg values are close to 0.33 but the Pr values are mostly between 0.34-0.36. This indicates the reflectances at R band are slightly larger than the reflectances at G and B bands. How to interpret this feature?

See reply to specific comment 1)

8) Section 3
is very helpful to understand the OCRA radiometric cloud fraction. Why not compare with GOME-2 L1 effective cloud fraction? By definition, the GOME-2 L1 effective cloud fraction would be more close to the OCRA radiometric cloud fraction than the AVHRR cloud fraction.

See author's reply to the second general comment.

A new Figure (Figure 26) has been included in the manuscript showing a comparison between the OCRA, FRESCO and AVHRR cloud fractions. Detailed explanations are also added to the manuscript.

9) Section 3.1
It is a good idea to apply the cloud optical thickness filter to remove thin and very thick clouds. Actually the filter removed most OCRA radiometric cloud fractions close to 0 and 1. In sect. 3, The authors attribute the mean difference between GOME-2 and SEVIRI cloud fraction to the insensitive of GOME-2 to the optically thin clouds. In section 3.1, the authors show that the cloud optical thickness filter does not improve the systematic offset of the cloud fraction. I suggest that the authors give more explanations about the results, for example the difference between the geometric cloud fraction and the radiometric cloud fraction.

The OCRA/AVHRR/FRESCO plot from the previous comment 8) will help to give more details here. See also the author's reply to comment 5) regarding the difference between the geometric and radiometric cloud fraction.

10) Fig. 16
The sunglint detection works well. I wonder if some real clouds are removed after the sunglint removal. The cloud fraction difference map has some large values, say 0.4-0.5, these might be real clouds. Will it help if a maximum cloud fraction threshold is included in the sunglint removal?

A maximum cloud fraction threshold might prevent to remove some real clouds but would also fail in the removal of true sunglint events which are above this threshold. Real clouds should feature a Stokes fraction close to zero. Applying a proper Stokes12 threshold should therefore prevent the removal of real clouds.