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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Cloud and surface classification using SCIAMACHY polarization measurement devices" *by* W. A. Lotz et al.

W. A. Lotz et al.

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We want to thank anonymous referee 1 for useful comments

To avoid confusions we refer to the referees comments by using page/paragraph.

Reply to "Specific comments"

1. Referee comment, S5387/1-2: The authors present a scheme of global thresholds to discriminate between cloudy and non-cloudy pixels as well as between cloud types (especially water and ice clouds) and different surface types (water, land, vegetation, desert, snow, ice and sun glint). On the one hand, the discrimination between clouds, surface, snow/ice and cloud free pixels is similar to

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existing publications, as mentioned by the authors (Krijger et al., 2005). For the discrimination between cloudy and cloud-free pixels over surfaces not covered by ice, the operational product OCRA is a better approach than the presented scheme. But on the other hand, some parts of the algorithm are quite interesting, especially the detection of sun glint and cloud phase, because a new approach is used for the determination of important information directly from SCIAMACHY data. But as outlined below, it is not worked out by the authors, that the retrieved thresholds are appropriate in general, including different seasons, viewing geometries, surfaces and dates of measurements. The paper should therefore only be accepted with major revisions, if the points stated below are clarified.

- The Optical Cloud Recognition Algorithm (OCRA) is described in Loyola (1998). As Tuinder et al. (2004) summarize the basic OCRA approach well and specify nicely the strengths and weaknesses of OCRA we would like to cite a part of their paper from subsection 3.4:

  The OCRA method has been implemented in the development version of the GOME Level 1-to-2 Data Processor and may be used as the default cloud fraction product in the future (von Bargen et al., 2000).

  The authors of this paper think that there are a couple of issues with the OCRA retrieval method. The method that OCRA uses to arrive at a cloud free reflection database is based on getting the point furthest away from 'white' in normalised rg-space, aiming to reach a value that will be cloud free and which also has the lowest reflection. The normalisation method uses the ratio of the reflections measured by the PMD channels and has lost information about the absolute value of the reflection itself. This normalisation and search mechanism does therefore not guarantee that values are indeed cloud free and correspond to the lowest reflectance available, although this minimum reflectance is required in the cloud fraction calculation phase.

  Visual inspection of the cloud free database of OCRA (made with this 'furthest *from white' method) shows a 'patchy' surface, while the PCRA minimum thresholds, which is a combination of independently ranked PMD channels, provides a more smooth image of the Earth. An example of this is shown in Fig. 4, where the three PMD components of the cloud-free database of OCRA and minimum thresholds of PCRA of a part of the Pacific Ocean are depicted in RGB color with equal scaling with respect to signal strength. These minimum threshold images were made using one month of data in August, but also three-year composites of August months show the same patchy behaviour from grid point to grid point in OCRA and did not seem to improve to the level of smoothness of a one month PCRA minimum threshold image. Although the Cloud Free database that comes with OCRADLR uses a complete year of PMD data, an RGB visualisation of this database this also shows a patchy behaviour. This means that part of the calculated pixel-to-pixel differences from OCRA may come from different minima rather than from real cloud features, especially when the retrieved cloud fraction is low.*

We agree with Tuinder et al. (2004). Beyond these aspects OCRA certainly has strength and represents a robust and very fast algorithm, but is problematic with respect to seasonality, at least when we consider the operational version where a complete year is used to determine global minimum reflectances. Therefore it is at least questionable that OCRA is a priori the superior tool for the discrimination between cloudy and cloudfree pixel as suggested by the referee. We have build our own implementation of OCRA to determine the quality of cloud fractions over large parts of the SCIAMACHY data set. Sometimes the results are not as clear as expected (patchy areas, especially in the Atlantic Ocean at the coast of Angola/Namibia). If a peer-reviewed validation paper for the OCRA algorithm exist we kindly ask the referee to send us a reference.
For the last part of the 1^{st} referee comment please see the answers to the 5^{th} and the 8^{th} referee comments (*sun glint and cloud phase*) and the answer to the 3^{rd} referee comment (*different seasons*).

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2. Referee comment, S5388/2-4: For the detection of clouds and the discrimination between different cloud types three values are used:

   - the average between the PMD intensities (b)
   - the range between the intensities of three PMDs normalized to the average r (similar to the saturation as used for pre-classification in the OCRA algorithm).
   - the intensity of PMD 5 (near-infrared)

   For surface classification (including sun glint), additional quantities are used: the vegetation index, the relation between PMD 7 and PMD 4, the relation between PMD 5 and PMD 4 and the intensity of PMD 4.

   The authors should add further references dealing with PMD cloud retrieval, especially publications of the OCRA algorithm, because the values b and r are quite similar (but not identical) to the values used in the OCRA algorithm for pre-classification. The authors may choose publications dealing with GOME data, because the SCIAMACHY algorithms are often based on earlier publications dealing with GOME-1 data.

- There seems to be a misunderstanding considering the values b and r:

  OCRA: OCRA uses the reflectances of three selected PMDs (3,2 and 1) $R = \rho(x, y, \lambda_R)$, $G = \rho(x, y, \lambda_G)$, $B = \rho(x, y, \lambda_B)$ to build a normalized RGB (rgb) representation of the color by transforming them into a rg–space as described in Loyola (1998). This is done by $r = \frac{R}{R+G+B}$, $g = \frac{G}{R+G+B}$ $b = \frac{B}{R+G+B}$. That means, b and r are the normalized blue and red components of a rgb representation which is the input for some distance calculations used to build up a minimum reflectance (cloud free) database .

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SPICS: SPICS does not really need a cloud free or a minimum database. SPICS uses the radiance ratios of PMD 7 and 4 and PMD 5 and 4 and the reflectances of five selected PMDs (7, 5, 4, 3 and 2). It is assumed that the reflectances of PMD (4, 3, and 2) are the components of a rgb composite: $R = \rho(x, y, \lambda_R)$, $G = \rho(x, y, \lambda_G)$ and $B = \rho(x, y, \lambda_B)$. Then $b = \frac{R+G+B}{3}$ can be seen as a brightness
while $r = \frac{max(R,G,B) - min(R,G,B)}{b}$ can be seen as relative deviation from a gray-value (gray value: all three reflectances have the same value). A value r which is near zero indicates that the input parameter of b are nearly equal sized.
Using all this mentioned values, and additionally some therefrom derived values and some geographical values the SPICS classification step starts.
PMD 1 is not choosen into account because of to high signal values compared with PMD(2, 3, 4).

As the referee suggested we will add the following additional references:

Loyola, D., "A New Cloud Recognition Algorithm for Optical Sensors", IEEE International Geoscience and Remote Sensing Symposium, IGARSS'98 Digest, Volume II, 572-574, 1998

Tuinder, O. N. E., Winter-Sorkina R. de , and Builtjes, P. J. H. Retrieval methods of effective cloud cover from the GOME instrument: an intercomparison, ACP, 4, 255-273, 2004

Von Bargen, A., Kurosu, T., Chance, K., Loyola, D., Aberle, B. and Spurr, R.: ERS-2, Cloud Retrieval Algorithm for GOME (CRAG), Final Report, Tech. rep., German Aerospace Center (DLR) and Smithsonian Astrophysical Observatory

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(SAO), 2000

3. Referee comment, S5388/5-6, S5389/1-2: With respect to Table 3/4, I think sensitivity studies have to be done to determine the conditions suitable for the usage of global thresholds, e.g. limits of the solar zenith angle, the surface albedo and the heterogeneity of the measurement in cloud cover and surface type. The last point is partly discussed by the authors, but not concerning the most interesting parts of the algorithm (cloud phase, sun glint).

   - the measured PMD intensities depend on the satellite geometry (solar zenith angle, line of sight angle, relative azimuth angle). For high solar zenith angles ($>$60 degrees) these effects are not negligible.

   - The cloud classification does not take the surface albedo into account, which is important in the case of partly cloudy pixels, but also for completely cloudy pixels, if the optical thickness is low. For several surface types the PMD intensity in PMD 5 for cloud free scenes is higher than the whole range defining "ice clouds" in Table 3. The strong effect of the surface albedo to measured intensities is the major reason, why simple cloud screening algorithms as developed in the 1990s for GOME are usually no more used with GOME/SCIAMACHY except for very rough estimations with an accuracy of about 20% in effective cloud fraction. But for the discrimination between water and ice clouds a higher accuracy is required.

- All thresholds were derived from a set of representative orbits. The referee is right to some extend. Indeed, we need to clarify further on which data base the thresholds have been determined. We will add the following to the publication:
  A representative set of SCIAMACHY-orbits have been utilized to derive the thresholds and constraints defined in Tab 3+4. All orbits in January 2006, April 2008 and July 2008 have been used for the derivation. The underlying data set consists of reprocessed, consolidated SCIAMACHY-L1-data. Only data with $SZA < 85^o$ *is taken into account.*

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For this reason impact of seasonality and viewing geometry are taken into account implicitly through the selection of the months (years) used. This approach ensured also that a variety of surface types as well as heterogeneity within the field of view of the PMD-measurement are accounted for.

The PMD 5 constraints for clouds will be applied only if the pixel has not been classified as an other surfce type solely in former tests (*... higher than the whole range ...*).

4. Referee comment, S5389/3: - Which corrections are used for the PMD intensities (ESA corrections, individual corrections) except dividing the radiance by solar irradiance and the cosine of the solar zenith angle? Is the instrument degradation taken into account?

- For Calibration and extraction of SCIAMACHY Level 1b data we used the newest SciaL1C tool from ESA Earthnet Online applying all calibration options enabled. Min/Max-analysis over all mission years have been performed in order to estimate the degree of the degradation. For PMD 2,3,4,5,7 this showed that degradation effects are negligible. This analysis also delivered a first estimation for the setting of some thresholds from Tab 3+4 which have afterwards been fine tuned as discussed in the reply to comment 3.

5. Referee comment, S5389/4: -on p. 9863 the authors mention, that a huge amount of MERIS data is used to determine liquid water classification. If the authors are able to apply a huge amount of MERIS data, i would suggest that a quantitative intercomparision of the retrieved cloud phase with MERIS should be added to the paper to show the reliability of the method. With respect to the points above, I think that the possible conclusions of the presented case studies are quite limited.

- We agree and will add this analysis into subsections 4.1 and 4.2. The results illustrate that there is a good quantitative and qualitative agreement between SPICS and MERIS family A (Upper clouds) and B (Middle clouds) cloud classifications.

6. Referee comment, S5389/5: - The statement in the abstract, that there is a good quantitative agreement between MERIS and the presented algorithms should be removed. For "water" the mismatches are nearly as large as the matches (20898/27801). The study indicates, that the reason is the heterogeneity of the measurements, but the problem is, that the people who want to use this algorithm with SCIAMACHY data has to deal with the algorithm without additional subpixel information.

- The abstract will be changed from:
  Qualitative and quantitative validation using MERIS satellite imagery shows good agreement.
  to:
  Qualitative validation using MERIS satellite imagery shows good agreement. The quantitative agreement is hampered by the heterogeneity of MERIS classifications within each SCIAMACHY PMD Groundpixel.

7. Referee comment, S5389/6-S5390/1: - The statement, that the algorithm can be applied to GOME-2 after adapting the thresholds should be removed (p. 9870) because the PMD in the infrared (PMD 5) is not available on GOME-2.

- We agree, the PMD range of GOME-2 is 300-800 nm. We will remove that statement.

8. Referee comment, S5390/2: - a validation of the sun glint retrieval including a huge dataset with different conditions (seasons, solar zenith angle, regions on earth) would improve the paper, but is perhaps not easy. I would say, hat it is not mandatory to add such a validation, if the authors are able to show the reliability of the cloud phase retrieval using an quantitative intercomparison.

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- First results of a sun glint validation have already been made. Validation using full resolution true color images of MERIS show very good agreement. A comparison on reduced resolution data level shows that SPICS sun glint is in even exzellent agreement with MERIS glint flagging. One MERIS glint flag (bit 2: high level glint) is calculated accounting only geometry aspects. The other MERIS flag (bit 4: medium level glint) additionally takes wind speed into account (surface roughness).
  A further discussion on this sun glint validation will be added in section 4.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 9855, 2008.