Atmos. Chem. Phys. Discuss., 5, S1254–S1265, 2005
www.atmos-chem-phys.org/acpd/5/S1254/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Distinction between clouds and ice/snow covered surfaces in the identification of cloud-free observations using SCIAMACHY PMDs" *by* J. M. Krijger et al.

J. M. Krijger et al.

Received and published: 17 June 2005

Response to Anonymous Referee #2 Comments

First we would like to thank the referee for his comments. Our replies to the comments is provided below in italics. A revised manuscript will be submitted incorporating all comments.

Anonymous Referee #2

Review on the manuscript: 'Distinction between clouds and ice/snow covered surfaces in the identification of cloudfree observations using SCIAMACHY PMDs' by J.M. Krijger, I. Aben, and H. Schrijver The paper addresses a very important issue: the discrimination of cloudy and ice covered scenes in satellite cloud retrievals. Such an identification can be interesting in itself and for the investigation of cloud properties. It is definitely important for the correct interpretation of remote sensing of tropospheric trace gases from space. The work convincingly demonstrates the principle possibility to distinguish between clouds and ice/snow covered surfaces using observations from the near infrared spectral range. They authors also develop a simple cloud algorithm using experimentally determined threshold values for the characterisation of the properties of individual satellite observations. This algorithm seems to work well for the selected case studies, but I have the impression that by far not the optimum use was made from the available information. In particular not enough emphasis is given to the physics 'behind' the algorithm. Instead, arbitrary thresholds are selected to satisfy arbitrary criteria.

The values for the thresholds are empirically determined using validated cloud information from MODIS. More information will be included on the MODIS method and validation of the MODIS cloud product. As discussed in the response to reviewer #1, comment 2, we will add information on the physical principles behind the chosen approach.

From a paper which introduces a new technique I would expect a deeper discussion of the most important fundamental mechanisms (scattering on cloud particles versus reflection on the surface) as a function of wavelength.

I have also other major concerns: -the presented algorithm is based on assumptions which are not proofed to be fulfilled (in particular concerning the dependence on viewing angle and SZA).

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We go deeper into this issue in the answers to several specific points below.

- no comparison with established cloud algorithms for UV/vis observations (e.g. FRESCO) is performed. Thus the quality of the part based on the visible PMDs can hardly be assessed.

SPICI is compared to MODIS, an instrument with algorithms designed for cloud detection. Comparing SPICI also to FRESCO, is identical to comparing FRESCO to MODIS and adds as such no scientific value. However we compared with cloud masks derived from FRESCO (considering all observations with an FRESCO cloud fraction lower than 0.10 as cloud free and higher than 0.10 as clouded) and SPICI agrees within few percent (except over desert areas where the currently used version of FRESCO data is know to be less reliable. (Koelemeijer 2002).

-the algorithm is adjusted (and validated!) using collocated MODIS observations. No sufficient information on the details and the quality of the MODIS cloud results are given.

We will include more background and references on the MODIS methods employed and their validation.

In the current version the paper is not suited for publication. After addressing the raised points I recommend publication in ACP. Specific points:

We shall incorporate the specific points into the revised manuscript as requested. Below we answer on those comments that require a more detailed explanation.

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6) equation 1 and following paragraph: This information is never used in the following and is thus misleading. Just say that the polarisation sensitivity of the PMD 2,3,4 is small and is thus neglected.

As the other referee requested more detail on this information, it is apparently not obvious enough to remove completely.

7) line 93/04: This statement is not clear to me. The second step is also part of the 'cloud algorithm'?

The SPICI algorithm consists of two parts. The first part is about detecting clouds (cloud algorithm), however this part will also identifies snow/covered surfaces as clouds. As such a second part is required that can distinguish between clouds and snow surfaces (Snow recognition).

8) line 120: Fig. 2 should be Fig. 1? (real Fig 2 is never mentioned in the text)

We shall remove Fig 1 as suggested by both reviewers and as such refer only to Fig 2.

9) Fig. 1 & Fig. 2: Both plots are 'nice', but what do they really tell? (What do you want to tell the reader?) The assignment of colours to the different PMDs is arbitrary and has no meaning. I recommend to remove both figures.

Fig 2, uses a colour assignment to recreate the familiar appearance of Earth in the visual wavelength range. This image shows to the reader that the PMDs can be used 'as is', without polarization correction or viewing geometry dependences. We shall

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remove Fig 1 as also suggested by the reviewer #1.

10) line 130: What do you intend to say with 'The image shows that PMD 2,3, and 4 can be used as broad band intensity measurements'? Isn't this clear at all?

See the point above.

11) Fig. 3: Why do you show a colour composite of PMD 4,5, and 6? There is no expression of the PMDs by real colours at all! This is confusing and misleading. If you want to show that PMD 5 can be used to discriminate between ice/snow and clouds, then just show individual figures for PMD 4 and PMD 5. You don't use PMD 6 later on. Why do you use it here?

The advantage of assigning colours to different PMDs is that it allows a one-to-one comparison between the same observation with different PMDs as the resulting colour indicates the (linear) combination of the different signals in each PMD. Individual images for the PMDs complicates the comparison between the images, as the reader has to search the same location in both images. The use of also PMD 6 in this image is for illustrative purpose only, combing all Infra-red PMD information into a single image.

12) line 150: What is the justification for the assignment to different colours? Non of the used PMDs cover the colour which is assigned.

This RGB coding however is used for saturation or 'whiteness' determination and as such do not represent real physical colours. As our saturation is only a value to derive whether an observation has similar high reflectance in all three visual PMDs,

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without reference to any real colours. We realize that this can cause confusion and will rewrite the section to use different acronyms (non-colours) in order to derive saturation.

13) line 154: What is the justification for the expectation that for cloudy scenes the intensities should be equal? Wouldn't this depend on the cloud type, altitude and solar zenith angle?

As shown in NASA Reference Publication 1139, 'Spectral reflectances of natural targets for use in remote sensing studies', by Bowker at all, 1985, clouds have a rather wavelength independent spectrum, especially in the visible wavelengths. While the measured integrated intensities for each observed cloud will be different (depending on cloud fraction, type, altitude and solar zenith angle) each individual spectrum will be rather wavelength independent. As such each individual cloud should have similar intensities in the different PMDs and it is this property that we use.

14) line 155: What do you mean with 'visually inspected'?

We selected several clouded observations by searching for observations showing bright reflectances in all three PMDs compared to their surroundings. This we later verified with the MODIS Cloud mask, which is not mentioned at this point in order to keep the flow of the article.

15) line 158: Why do you use two names 'whiteness' and 'saturation'? This is confusing.

The correct technical term is saturation, however for clarity the more easily interpretable term whiteness is used where appropriate, eg, in the summary at the end of

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section 3.

16) line 163: You state that your saturation value does not depend on viewing angle and solar zenith angle. There is no justification given for this statement. I have doubts that it is really true. I would especially expect a dependence on the solar zenith angle. Please provide a diagram showing your saturation values as a function of viewing angle and SZA.

While measured reflectivity by a single PMD is dependent on SZA (changing the reflected solar flux received) and viewing angle (due to instrumental effects), these dependencies disappear (mostly) when taking the ratios between two PMDs. As such a ratio between PMDs requires no correction for SZA or viewing angle, which is what we refer to in our paper. The derived parameter from this ratio (in this case saturation) might be dependent on many different factors (including SZA). However as SPICI thresholds are empirically determined with MODIS any remaining dependency is further accounted for in these thresholds.
Studying the data indeed a small dependence of SZA on saturation can be found, however this dependence only becomes significant at very high latitudes where the saturation increases with SZA, however still well within SPICI thresholds
Adding a SZA vs saturation diagram does not add significantly to this paper, however if desired diagrams will be made available to the editor for distribution to the referees.

17) paragraph after line 165: Please provide references for the MODIS algorithm. How are the MODIS cloud mask values are derived?

MODIS uses several different tests to determine whether or not the field of view is obstructed by a cloud. Describing all tests in detail is not within the intention of this study and would increase the length of the article overly. The tests are described by

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Ackerman2002. We shall include short descriptions in the revised manuscript and a reference to Ackerman2002.

18) line 181: What is the justification for averaging the MODIS cloud values? Are the values proportional to cloud properties, e.g. cloud fraction?

MODIS cloud values indicate only the (possible) presence of a cloud within a 1kmx1km box, averaging over e.g. 200 MODIS observations within one SCIAMACHY pixels does give an indication how many clouds (e.g. cloud fraction) are with certainty present inside the SCIAMACHY pixel. The values 0 and 3 are the extremes in MODIS (certainly clouded, certainly cloud-free), while values 1 and 2 indicate a the possibility of the presence of a clouded/cloud-free scene with much lower certainty. As such we focus on MODIS averages around 0 and 3 where the results (clouded or not) are very certain according to MODIS. Not averaging (but e.g. selecting only whether or not 1 single cloud was present in the SCIA pixel) would have been a too strict, as we deem 2-5 MODIS pixel sized uncertain clouds within a SCIAMACHY pixel not to affect other analyses (that might use SPICI as cloud mask).

19) line 185: What do you mean with 'wrong signature'? How well does the MODIS algorithm describe reality? Are there any validation results?

With 'wrong signature' we refer to misidentification: where a scene was designated clouded, while being clear in reality and in reverse. The text has been changed to more clearly explain this. MODIS algorithm and validation references will be added to the article.

20) line 205: For your case study you selected scenes with sharp cloud contours. What will happen for optically thin clouds without sharp contours?

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We selected our scenes only on the presence of potentially snow/ice covered surfaces (Antarctic/Greenland) and clouded regions and overlap between the instruments for development of the algorithm. No special selections were made on cloud properties. The images shown are all from the MODIS cloud flag product, which does not make a distinction between optically thick or thin clouds and is given at a resolution of 1kmx1km, which might give the impression of sharp contours. As such MODIS does not make a distinction between the two cases (and thus nor SPICI).

21) Did you compare your algorithm (visible part) with existing cloud algorithms (e.g. FRESCO)?

Beside the comparison with MODIS (an existing validated cloud algorithm) we also compared with FRESCO cloud masks (considering all observations with an FRESCO cloud fraction lower than 0.10 as cloud free and higher than 0.10 as clouded). SPICI agrees within few percent (except over desert areas where the currently used version of FRESCO data is know to be less reliable. (Koelemeijer 2002). Including a FRESCO comparison would lengthen the paper considerably but not add significant scientific content.

22) line 239: An insufficient calibration should only result in a bias of the ratio of PMD 5 and PMD 4. (If signal to noise is really a problem, you can't use the PMD observations at all). It would be interesting to see, if the ratio shows a lower fixpoint for snow/ice covered surfaces.

The mentioning of a relative calibration of the PMDs was confusing, and referred to a calibration used for the polarisation-correction of the main science channels in combination with the PMDs but this calibration can not be used for the absolute calibration of the PMDS. As such no absolute calibration exists for the PMDs, which is

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why the thresholds for the ratios had to be determined empirically. We changed the text to remove this confusion.

23) line 243: Again you state that the ratio is independent on viewing angle and solar zenith angle without proof. Please provide a figure with ratio as function of SZA and viewing angle. (What is the characteristic of the BDRF of snow/ice?)

See the answer to point 16, which also applies here, the paper states that no corrections are needed, not whether a dependence might be present. The ratio itself is only very slightly dependent on viewing angle and SZA, most likely due to polarisation effects (see comments to referee #1), but this effect is much smaller then the effects we are interested in. We shall rephrase this in the article.
Adding a SZA or viewing angle vs. ratio diagram does not add significantly to this paper, however if desired diagrams will be made available to the editor for distribution to the referees.

24) line 250: How strongly does the surface albedo of snow and ice differ for different conditions (e.g. new or old snow)? How would this affect the ratio?

As shown in Greuell 2004, different snow conditions can affect the surface albedo, but all different snow/ice conditions (for varied amounts of dirt and compactness) show a strong decrease in albedo between 800 and 1600 nm. So all these different conditions fall well within our defined thresholds.

25) Fig. 7 & Fig. 8: You find different distributions for Antarctica and Europe and you adjust your thresholds accordingly. Do you have an explanation why the ratios for cloudy scenes are different for both scenes? Could this be a remaining solar zenith angle dependence? (see points 16 and 23).

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The difference in ratios is most likely due to the difference in surface reflectivity, as over Antarctica only a snow background exist, while over Europe many different kind of backgrounds (sea, vegetation etc). Note the difference in ratios for clear pixels between these two areas. Another reason for the difference in ratios might simply be statistics. The variation in ratios is not well enough sampled in the relatively few measurements over the Antarctic, while the observation over Europe has more measurements and can thus sample the more extreme values in ratio. No dependence on SZA could be found in these datasets.

26) section 5: This is no independent validation, because you compare your algorithm to another algorithm to which it was previously adjusted.

The SPICI thresholds have been derived with the intention of providing a usable cloud mask. MODIS provides an independently validated cloud mask. The SPICI thresholds have been derived from a limited set of scenes. We validate whether our thresholds can be used on a global scale by comparing with different observations at different geolocations from the one used to derive the threshold values. As MODIS has been independently validated, SPICI can be validated using MODIS data, as long as we use a different dataset for the validation and the derivation of the thresholds.

28) Fig. 6: What is the reason for the different spectral dependence (of blue and red line) within the spectral range of PMD 4?

The different spectral behaviour within the spectral range of PMD 4 is due to absorption in the O2A-band up to 790nm. If a cloud is present the total sampled O2 column is smaller and as such less absorption is measured. Wavelengths higher then 790mn are mostly dominated by water vapour and show more absorption when a cloud is present.

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29) Do you have an explanation for the 'blue values' with ratios > 0.4?

Visual inspection has shown these to be observations at the edge of large cloud complexes or patchy cloud regions. Movement of clouds in-between the overpass time of SCIAMACHY and MODIS can cause disagreements between SPICI and MODIS. Also due to the size of the plotting symbols underlying symbols are sometimes not visible. As such this image can be confusing and it will be removed. The good agreement between SPICI and MODIS we tried to show in this image will be put in tabular format and better described in the text.

With friendly greetings,

J.M.Krijger, I. Aben & H. Schrijver

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 815, 2005.