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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.

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Response to Anonymous Referee 1 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 #1

The paper is a technical description of how to distinguish between between clouds and ice surfaces given the polarisation detectors (PMDs) of SCIAMACHY. The aim of this distinction is to identify cloudfree scenes for study of tropospheric trace gases with SCIAMACHY. The paper can be useful for people who want to perform this distinction using PMDs alone. Generally speaking, the paper should be made more scientific by improving the physical background, and by giving more quantitative information on the comparison results. Specifically, I have the following major criticisms on the manuscript (points 1-6), which have to be addressed satisfactorily before the paper can be accepted for ACP (substantial revisions). In addition I have some more technical and/or detailed comments, points 7-25.

1. The PMDs are specially designed polarisation detectors. However, polarisation correction of the PMD signals themselves is not performed in this paper. This is strange, and contradicts lines 98-103. The error which this missing polarisation correction of the PMD signals is causing on the PMD cloud detection and ice detection has to be assessed. Please note that especially at high latitudes where snow/ice surfaces occur, the solar zenith angle is large and consequently the degree of polarisation may be high, also in PMD2 and PMD3. There it is not true that the degree of polarisation q=Q/I is less than 0.1, as stated on line 117, since q can be much larger.

Indeed for high solar zenith angles the degree of polarization may become larger than 0.1, especially for PMD 1 which does require correction, however for the PMDs used in this study there are several reasons why the effect of polarisation on the final (cloud/ice) product is very small. First, the variation in measured intensity is several orders of magnitude smaller than the variation in measured intensity due to changes in ground albedo. This is demonstrated in Fig 1 and 2, where from PMDS with no polarisation correction applied, an image of the earth is constructed. In this image no polarisation features can be seen. Second, all used parameters (saturation and ratio) are derived from ratios between different PMD's, as such polarisation effects are in part divided out except for any difference in polarisation-effect between the

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different PMDs. All PMDs (except PMD 1 and 7, not used in this study) are very similar in their polarisation-sensitivity; as such any difference should come from the variation of polarisation in wavelength between PMDs. However all PMDs used have little variation in polarisation between them, and again much smaller than the variation due to ground albedo) which is relevant for the distinction of ice/snow from clouds.

2. The spectral difference at 1.6 micron between clouds and ice/snow surfaces is not explained in a physical sense. The reason of the difference is the difference in refractive index (imaginary part) between water and ice particles, and the difference in size of the particles. There are many publications on the 1.6 micron absorption features of water/ice, and already some publications aimed at using SCIAMACHY channel 6 data for cloud phase discrimination (Knap et al., JAS, 2002, Acarreta et al., Atmos.Res., 2004). The paper lacks a reference on the physical principle, and the use of SCIAMACHY near-IR spectra for distiction between water and ice. See also next comment.

In this study we do not use the spectral slope around 1600nm, but the relative difference in broadband spectral reflectance between 800nm and 1600. This difference in reflectance at these wavelengths for clouds vs ice/snow surfaces is presented in NASA Reference Publication 1139, 'Spectral reflectances of natural targets for use in remote sensing studies', by Bowker at all, 1985 and is due to strong absorption from overtones and combinations of the three internal and fundamental modes of the water molecule with each other and the lattice vibration modes (Johari 1981). We will include this information on the physical background behind our method in our revised manuscript.

3. The paper does not make a difference between types of clouds. There are water clouds and ice clouds (and mixed-phase clouds). Ice clouds have a similar spectral behaviour as ice/snow surfaces. Therefore, the distinction proposed in this paper be-

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tween clouds and ice surfaces will probably not hold for ice clouds. This limitation has to be mentioned clearly.

We are not aiming to distinguish between water and ice clouds in this study. The main aim is to identify cloud contaminated observations over ice/snow surfaces. The MODIS cloud-mask also does not make a distinction between clouds types, but is sensitive to all types. MODIS detect both water and ice clouds, and we verified that when using the correct ratio between PMD 4 and 5, SPICI also detects both (without making distinction between them). We will add ice-cloud spectra in the cloud-ice spectra comparison image (Fig 3) that will show this.

4. The signals of the PMDs are not calibrated. Therfore, they do not have a physical meaning, and are only instrumental counts. The given criteria for thresholds are therefore only instrumental values. The data processor version should be mentioned, since the counts may be different for different processor versions (due to corrections for dark current, stray light, etc.).

We shall mention processor version. The provided thresholds have been derived for SCIAMACHY processor version 5.04, but can be used on earliers version, as the changes in raw PMD measurements are less than a percent for the PMDs used by SPICI.

5. I have problems with the RGB colouring as used in Figs. 1 and 2, in Eq. (2) and in the footnote on p. 5:

(a) There is no green in PMD3! The wavelength range of PMD3 is 610-690 nm according to Table 1. Green, however, is around 550 nm, where the chlorophyll spectrum has a peak. So it is not possible to get a green colour from PMD3. Perhaps, in the SPICI

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algorithm green is made as a pseudo-green colour from the PMD4 signal? Beyond 700 nm vegetation is highly reflective, so PMD4 has a high signal.

Indeed, because of the high reflection of vegetation, PMD4 is used both as a pseudo-green and pseudo-red to construct Fig 2. The SPICI algorithm uses PMD 3 as Green, in the RGB composition to derive a saturation. This RGB coding however is only used for saturation or 'whiteness' determination and as such do not represent real physical colours. Actually our saturation is a parameter to determine whether an observation has similar high reflectance in all three visual PMDs, without reference to any real colours. We realize that this can cause confusion and will rewrite the section using different acronyms (non-colours) in order to derive saturation.

(b) Figure 1 can be removed, since this colour coding is apparently not useful. Fig. 2 is a much realistic true colour figure. However, this figure was made with the RGB coding of the footnote on p. 5. Move therefore the footnote to the main text or to the figure caption.

To avoid confusion we shall remove Fig 1 and its colour coding.

(c) There is confusion on the preferred RGB colour scheme according to this paper: Eq. (2) seems to be a third variation of RGB colouring, in addition to that of Fig. 1 and Fig. 2.

See comments on point 5a and b. We shall in the revised manuscript refer to only one RGB colouring.

6. Fig. 12 shows that the saturation parameter S is not such a good quantity to separate clear from cloudy scenes. The branch on the right-hand-side contains a mixture of blue

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and red points (confidently clear and confidently cloudy points according to MODIS). The agreement between SPICI and MODIS is less good than claimed on line 316 of the paper. The actual (dis)agreement between the SPICI results and the MODIS results should be made more quantitative: give the percentage of successful and unsuccesful identifications by SPICI for clear and cloudy scenes.

We shall include the percentages of successful and unsuccessful identifications by SPICI when compared to MODIS, in both tabular form and described in the text.

Detailed comments:

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

9. It should be mentioned that cloud detection methods using the O2 A-band, like FRESCO and SACURA, are also detecting the pressure of the clouds or the surface. The pressure can be used to discriminate white clouds from a white surface.

Although this in principle true, the current existing FRESCO an SACURA algorithms do not use this information of the pressure to distinguish between clouds and ice/snow covered surfaces.

10. l. 80: How does MODIS separate clouds from snow/ice surfaces? This has to be mentioned.

MODIS uses several different tests to determine whether or not clouds are present of snow/ice covered surfaces. Describing all tests in detail is not within the intention of

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this study and would increase the length of the article overly. The tests are described by Ackerman2002. We shall include short descriptions in the revised manuscript and a reference to Ackerman2002.

13. On l. 123 it is said that each PMD signal is corrected for the viewing zenith angle (VZA) and solar zenith angle. Please specify how this is done. Why is a correction for the viewing zenith angle needed? I hope you do not mean a factor 1/cos(VZA), because that would be erroneous.

The reference to correction for viewing zenith angle was wrong, as no such correction was used for Fig 1-3. The correction for solar zenith angle was indeed 1/cos(SZA).

15. What is the used MODIS image resolution? There are different values mentioned on lines 171 and 180.

L171 mentions that MODIS has data-products varying in resolution between 250mx250m and 5kmx5km, while L172 mentions that we used the 1kmx1km cloudflag product, which is repeated on L180 (for comparison with the SCIAMACHY spatial resolution).

17. Eq. (4) can be removed. The single threshold value can be mentioned in the text. Furthermore, it is repeated in the recipe of the method given in Eq. (6).

Eq 4 and 5 defines the thresholds derived and described in section 3 and section 4, respectively. With eq 6 the summary of the thresholds for the full SPICI algorithm. While Eq 6 summarizes all threshold. We would prefer to keep these equation in for clarity.

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19. Eq. (3) should be clarified: to which set does the min and max refer? One state, one orbit, or one year of data?

Max en min refer to the maximum and minimum of the three weighted PMD measurement of the ground pixel involved. Given this confusion and the RGB confusion we shall rewrite this paragraph more clearly.

20. Fig. 4: For how many SCIA states is this comparison between SCIA and MODIS performed? What was the underlying surface? The threshold for S, 0.35, is apparently based on this limited set of data. How reliable is its application to global data from SCIAMACHY, where different surfaces and cloudy scenes may occur?

The data compared in Fig 4 is the same data visually shown in Fig 5 (over Europe/Africa). As such 6 SCIAMACHY states were used, with varying underlying surfaces. The later presented results of SPICI over Greenland validate that this ratio is reliable and can be applied globally.

21. The spectra of Fig. 6 apparently are not including ice clouds, but only water clouds. Ice clouds might also be dark in PMD5. This should be mentioned in the description.

See response to comment 3, we will include ice clouds spectra in Fig 6 for completeness.

22. Figs. 10 and 11 have a too complicated colour coding. The legend is not clear. In addition, the legend is hiding part of the relevant parts of the image.

The complicated colour coding is necessary in order to include all information. However we shall replace the figure with a less complicated colour coding, showing

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MODIS only clouded or clear scenes instead of 'Cloud', 'Maybe Cloud', 'Maybe Clear', 'Clear', as the 'maybe' Identifications occur rarely and only near cloud edges at a resolution that SCIAMACHY cannot resolve.

With friendly greetings,

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