Authors response to the comments by Anonymous Referee #2

General comments:

The authors presented a new cloud detection method for MERIS. The method adopts the Bayesian concept with the feature vector including three parameters: O2 A-band ratio, MERIS differential snow index, and brightness and whiteness. The authors also developed a new method to correct the smile effect. It is found that the new method improves the current one significantly. The paper is relevant to the community. I recommend publication after addressing the issues listed below.

The authors are grateful for the positive review and appreciate the effort of the reviewer!

# When applying the O2 A-band ratio for cloud detection, as the authors pointed out, rox is dependent on the reflectance at 779 nm, but I didn't see where this is reflected. It seems the data were not binned by the 779nm reflectance. How is it taken into account in the cloud detection algorithm?

The reviewer has probably meant the text on Page 7 Line 26-29. In this part, we present the correction of the systematic offset due to the smile effect and not yet the cloud screening itself. The text on Page 7 Line 26-29 describes the dependencies of  $r_{\alpha}$  which were considered to try and remove the systematic offset so that r<sub>a</sub> can be further used to derive cloud probabilities. The authors thank the reviewer for noticing this writing mishap. This part of the text stems from a draft version of the manuscript and needs to be updated. Indeed, the dependence on 779nm reflectance has not been considered in the current version of the manuscript, as can also be seen in the following equations. The problem with taking the surface reflectance into account by using the 779nm channel lies in the fact that the statistical majority of cases where the correction has to be performed is located in a relatively narrow range of surface reflectances (corresponding to wet ice/bare ice with ~20% melt ponds, a widespread situation during Arctic summer), which would correspond to only one or two bins when binning over 779nm. The sample size for the other bins (darker or brighter surface types) is orders of magnitude smaller, unevenly distributed and is not sufficient to develop a statistical correction. This can be seen in Fig. 2 where a discrepancy of less than 2% of  $r_{\alpha}$  value is shown when comparing corrections for the entire summer (black curve) with averaged May or July (red and blue curves). One can say, the dependence on the surface albedo is not so pronounced for the r<sub>a</sub> ratio, which of course is only valid for the ratio and would not be the case for a single oxygen absorption band R11. However, as our purpose was the relative correction of the smile effect for effective usage of cloud screening thresholds and not (as e.g. in Jäger, 2013) an absolute calibration of the R11 reflectance distorted by the smile effect, the achieved accuracy of the correction of a few percent (as shown in Fig. 2) justifies the selected approach.

In turn, the sum of the solar and viewing zenith angles turned out to give a better reflection of the daily cycle in comparison to the detector index and solar angle alone, so that the viewing angle has been included into the correction scheme.

In the new version of the manuscript, the text at Page 7 lines 25-32 was therefore updated as follows:

"We assume that  $r_{\alpha}$  depends on three parameters: the detector index  $I_{\alpha}$  which corresponds to the position of the pixel in the detector array, the sun zenith angle  $\theta_s$  and the viewing zenith angle  $\theta_v$ .  $I_{\alpha}$  gives a pixel's position in the sensor array and allows to compensate for the spectral *smile* effect. The sun zenith angle  $\theta_s$  and the viewing angle  $\theta_v$  allows estimating the optical path in the atmosphere which is in direct dependence with the oxygen absorption. The seasonal nature of  $r_{\alpha}$  dependence on surface reflectance e.g. at channel 779nm presents a challenge of statistically non-uniform bins of very different sample size and was not included into the correction scheme. The residual rox dependence on the surface reflectance is less than 2% (Fig. 2) and does not prevent the application of the cloud screening routine."

The indices in Eq 3-4 were corrected to  $\theta_{sum} = \theta_s + \theta_v$ 

### There are many acronyms not having the fully spelt version. Please check.

This is also the point highlighted by the other reviewer and the new version of the manuscript has fewer and clearly defined acronyms.

#### Specific comments:

## P2, L14-16: why would "the retrievals of MPF and albedo discussed in this work misinterpret the cloud contamination as melting sea ice"? Doesn't melting sea ice have very different spectral signature with cloud?

The melting sea ice displays a variety of spectral behaviors in the entire range from white ice to dark melt ponds (e.g. see Istomina et al., 2012, PANGAEA dataset of sea ice spectral albedo during Arctic summer). The specifics of the MPF and albedo retrieval is such that not only this large range of surfaces but also their subpixel mixtures in various fractions have to be represented. This requires a versatile forward model and retrieval which can account for sea ice variability at a global spatial scale (see Zege et al 2015). In the given spectral range of the MERIS (412.5 - 900nm) clouds do not differ from the variety of surfaces available during Arctic summer to the point of clear distinction. So that e.g. warm water clouds look similar to white ice throughout most of the available spectral range (same for cirrus and fresh fine snow). This results in the fact that the retrieval does confuse their reflectances and relies on additional cloud screening.

### P4, L1: Since MERIS does not have SWIR channels, how is NDSI derived?

What is meant here is that the NDSI-like threshold is used, in this case the MDSI - MERIS Differential Snow Index. It is derived using two channels (865nm and 885nm) and utilizes the specific grain size feature of snow which is absent in other surfaces. The MDSI of this kind has been used e.g. by Schlundt et al (2011) and is also used in the presented work (see Eq. 8)

### P7, L6: Please consider changing "uniformly distributed" to "well mixed"

Thank you for this remark, the text has been changed accordingly.

### P9, L5: "Clear sky pixels that show open water are excluded during this step". Is there a pre-step that determines clear vs cloudy? How does this work inside the cloud detection algorithm?

Indeed, there is a pre-step that removes all open water pixels from the correction dataset. The latter is done as described by Schundt et al (2011) using thresholds on reflectances at channels 12 and 13, with the threshold values 0.09 and 0.08, respectively. The result is that the correction values for each detector index are then produced excluding the dark pixels. There is no distinction of clear and cloudy at this point as it is only the step to remove the systematic across-track variability so that the MDSI feature is not affected by it, and we can apply this feature more effectively.

The sentence: "Open water pixels have been removed using two thresholds on channels 12 and 13 as described by Schlundt et al. (2011)" has been added into the text as clarification.