<u>We thank the reviewer for his helpful comments which certainly have helped to improve the manuscript significantly.</u>

The reply is structures as follows. Reviewer comments have bold letters, are numbered, and are listed always in the beginning of each answer. The reviewer comments are followed by the authors comments with an explanation if necessary and revised parts of the paper. The revised parts of the paper are written in quotation marks and italic letters.

<u>Major comments:</u>

1.) **I believe that the authors of this study have not used all information which they obtain from the measurements. From the description of the retrieval method it is not clear whether several wavelength are used or whether only one wavelength is fitted to model simulations.**

➔ We agree that we did not sufficiently discuss the choice of the wavelength. Although the spectral imager detects radiation between 400 nm and 970 nm in this study only one wavelength (530 nm) was used. A single measurement at one visible wavelength channel is sufficient to retrieve cirrus optical thickness in this first feasibility study to show the capability of the instrument. The 530 nm wavelength was chosen to allow a comparison to the available Raman lidar at Deebles Point. In future studies the number of wavelength used in the retrieval might be extended to reduce the uncertainty of retrieved cloud optical properties. Additionally the full spectral radiation will help to better exploit the wavelength dependencies of cloud-aerosol-radiation interactions.

➔ In the manuscript this is now pointed out more clearly (at the end of the Introduction and in the beginning of chapter 3 "Retrieval of cirrus optical thickness").

> *"It needs to be mentioned that this study does not fully capitalize on the hyperspectral capabilities of AisaEAGLE. Here only one wavelength (530 nm) is used. Thus, the paper is regarded to be a first feasibility study to show the potential of AisaEAGLE for ground-based measurements of downward solar spectral radiances and for retrievals of cloud microphysical properties like the cirrus optical thickness from the spectral measurements. In future studies the wavelength range used for data evaluation will be extended to increase the number of retrieved cloud optical properties."*
>
> *"In a first feasibility study the simulations were performed for 530 nm wavelength only, which was chosen with regard to the wavelength of the LIDAR measurements at BCO."*

➔ To avoid any confusion in the revised manuscript we omit to call the measurements "hyperspectral". The title do not includes the word hyperspectral anymore.

> *"Retrieval of Cirrus Optical Thickness and Assessment of Ice Crystal Shape from Ground-Based Imaging Spectrometer Measurements"*

2.) The retrieval description is generally not very clear, the authors do not explain, how exactly the fitting to model simulations is done. The retrieval method should be described in more detail.

➔ Thanks for this comment. It is true that the fitting method which is essential for the retrieval algorithm was missing. A paragraph with a more detailed description of the retrieval method and how exactly the fitting to model simulations is done is now included in chapter 3 “Retrieval of cirrus optical thickness”.

> *“Using these input parameters, downward solar radiance $I^{\downarrow}_{cal}$ was simulated as a function of a set of different τ_{ci}. The simulations were performed for the whole FOV of AisaEAGLE and are interpolated over the entire period of each measurement. For each time stamp of the measurement and for each spatial pixel a simulated grid of possible radiances $I^{\downarrow}_{cal}$ and corresponding τ_{ci} is available. The retrieved τ_{ci} is derived by interpolating the simulated radiances to the measured value for each spatial pixel using a linear interpolation. To handle the ambiguity of the simulations, only cloud optical thickness below the maximum radiance were considered.”*

3.) My major concern is the result of the sensitivity study with respect to effective radius. I cannot believe that the resulting optical thickness should not depend on the assumed effective radius. Since optical wavelengths are used for the retrieval, the following relation is valid according to geometrical optics:

$$\tau \propto \frac{IWC}{R_{eff}} \quad (1)$$

Here *IWC* is the ice water content and Reff the effective radius. *IWC* is constant (the real *IWC* in the cloud). If the assumed R_{eff} is two times larger than the real R_{eff}, this would mean that the retrieved optical thickness should be too small by a factor of 2. I recommend to investigate this issue thoroughly before the paper is published in AMT.

➔ This concern does not apply for the retrieval approach used in our study as the IWC is not assumed to be constant. If we retrieve two different τ_{ci}, the IWC will change as R_{eff} is assumed to be constant. That might be contrary to the real world if it is seen from a microphysical point of view where a cloud can only have one fixed IWC. But our intention is not to retrieve IWC but to retrieve τ_{ci}, which is the most essential cloud property with regard to cloud radiative forcing. So in our world a cloud only has one fixed τ_{ci}. A proper retrieval of IWC is not possible with the method described here, as R_{eff} has to be assumed to be fixed and the measurements are not sensitive to R_{eff}. If R_{eff} would be simultaneously and independently retrieved, as we plan in future with an extension of the measured wavelength range, Eq. 1 can be used to obtain IWC.

➔ However, to better explain the physics behind the measurements and retrieval results, we included a plot of the scattering phase functions instead to explain the sensitivity to the ice crystal shape and the effective radius. Looking at the scattering phase functions it is easy to figure out why the results are less sensitive to the effective radius, but highly sensitive to the different ice crystal shapes. In the range of scattering angles observed in the four cases (highlighted grey in Figure 9), the phase functions are mostly similar when comparing different effective radii but show significant different values for different shapes. A discussion on the connection between scattering phase functions and sensitivities is given in the revised manuscript.

"Comparing the scattering phase functions in Figure 9b it can additionally be seen that, except in the maximum of the halo region and below 20°, over most of the captured scattering angle range they are quite similar. Since the differences between the scattering phase functions calculated for different r_{eff} appear mostly in the forward and backward scattering range but not in the captured scattering angle range, this explains the small variation found in the sensitivity study."

Minor comments:

l 83: Please explain "enhanced absorption"

- ➔ The part with "enhanced absorption" has been removed, because the mentioned problem is more related to the second part of this sentence.

  "This disagreement has not been resolved yet, partly because it has been extremely difficult to collocate remote sensing above the clouds and concurrent in-cloud microphysical measurements."

l 307: What is the "Hey" parameterization? This is not mentioned in Yang et al. 2000.

- ➔ The so-called HEY (Hong, Emde, Yang) parameterization was used to describe the single scattering properties of ice crystals. It uses pre-calculated ice cloud optical properties including full phase matrices. For this the single scattering properties have been generated by Hong Gang using the models by Yang et al. 2000. This is explained more clearly now.

  "The so-called HEY (Hong, Emde, Yang) parametrization was used to describe the single scattering properties of ice crystals. It uses pre-calculated ice cloud optical properties including full phase matrices generated with the models by Yang et al. (2000)."

l 327: Please specify the aerosol type more detailed. How is the "maritime aerosoltype" defined?

- ➔ libRadtran provides calculated Mie-tables for rural, maritime, urban and tropospheric aerosol size distributions given in Shettle (1989) (Shettle, E.: Models of aerosols, clouds and precipitation for atmospheric propagation studies, in: Atmospheric propagation in the uv, visible, ir and mm-region and related system aspects, no. 454 in AGARD Conference Proceedings, 1989.). Because the measurements were performed in the vicinity of the coast, the maritime aerosol type was chosen. This is now inserted in the text.

  "libRadtran provides calculated Mie-tables for rural, maritime, urban and tropospheric aerosol size distributions given in Shettle (1989). Because the measurements were performed in the vicinity of the coast, the maritime aerosol type was chosen."

l 382: Why is the 22 degree halo not visible in Fig.9 which includes the scattering angle of 22 degrees?

- ➔ Thanks for pointing this out. The halo is quite hard to figure out in Fig. 10 (Fig. 9 in the past) due to the cloud inhomogeneities and because of the halo itself, which appears to be quite weak. The averaged radiance displayed in Fig. 12 confirms this. The halo can be seen in the averaged data. However, due to the low cirrus optical thickness τ of 0.2 the maximum of the enhanced radiance within the halo region is relatively low.

> *"Comparable to the all-sky image enhanced radiance is measured for scattering angles of about 20° to 26°, indicating the halo. The halo is quite hard to figure out in Figure 10 due to the cloud inhomogeneities and because of the halo itself, which appears to be quite weak. The averaged radiance displayed in Figure 12 confirms this. The halo can be seen in the averaged data. However, due to the low τ_{ci} of 0.2, the maximum of the enhanced radiance within the halo region is relatively low."*

Technical corrections:

l 198: perpendicular cloud ... -> insert speed

- ➔ "perpendicular" inserted

l 555: quit -> quite

- ➔ corrected