# Amt-2022-87 Authors' Responses to Anonymous Referee #3

The authors would like to thank anonymous referee #3 for continuing to provide thoughtful feedback on the manuscript contents. The original comments by referee #3 are presented first, followed by the author response in italic font and then the respective changes to the manuscript.

# Responses to Anonymous Referee #3

The authors have provided adequate explanations to most of my comments. However, there are still a couple of unclear descriptions in the current manuscript, which should be improved before publication. The topic presented in this paper is suitable for Atmospheric Measurement Techniques. I recommend Minor Revisions for publication.

**Comments**

*Backscatter coefficient derivation from ECP data*

1. The authors' response to my first comment on the backscattering coefficient derivation from ECP data went off what was supposed to be. A main focus of the first comment was the definition of the backscattering efficiency. Although I suggested the authors to clearly define the backscatter efficiency in the manuscript in the previous round of review, it has not been specified in the current manuscript. The below definition of the backscattering efficiency is commonly used for remote sensing of ice clouds based on micro pulse lidar observations

$$\boldsymbol{Q_{back}} = \frac{\boldsymbol{Q_{ext}\omega P_{11}(\pi)}}{\boldsymbol{4\pi}}, \qquad (R1)$$

where $Q_{ext}$ is the extinction efficiency; $\omega$ is the single-scattering albedo; and $P_{11}(\pi)$ is the scattering phase function at 180° degree. Substituting Eq (R1) into $Q_i$ in Eq (4) gives exactly the backscattering coefficient under the assumption of the projected-area-equivalent sphere radius in Eq. (4), as the extinction/scattering/absorption/backscattering efficiencies are the quantities relative to the projected area of a particle. Therefore, I agree with the authors' statement that the area-equivalent sphere diameter/radius is typically more acceptable. Also, I would like to argue that the backscattering coefficient should be related to the projected area of a particle (i.e., should be the area-equivalent radius in Eq. 4).

In addition, 180 in Eq (5) should be $2\pi$ due to the radian unit in trigonometric functions. Please improve the corresponding descriptions.

On the backscattering coefficient derivation from OID data, I read Ray and Anderson (2015) and understand that the lidar ratio is derived by curve fitting of the two-way attenuated backscattering intensity measured from OID. Although the authors' response to the comment were somewhat inconsistent with what the paper described, the corresponding descriptions in the revised manuscript are now all consistent and clear.

*The authors feel that they now understand what is being requested of the backscatter efficiency equation, which has been added to the manuscript. Updates have also been made to further clarify that Eq. 4 is utilizes the area-equivalent radius. It is correct that Eq. 5 should integrated to $2\pi$ and this has been updated in the manuscript.*

***Changes:*** *Line 254 has been updated to specify that $r_i$ is the area-equivalent particle radius. The backscatter efficiency equation has been added as Eq. 5, with all following equations adjusted up* *one number and a description of Eq. 5 added at lines 260 - 264. Eq. 6 has been updated to replace "180" with $2\pi$.*

2. I am confused with an inconsistent description in the revised manuscript that *"For water spheres, πr2 is the cross-sectional area (A), while for irregular particles such as ice, A is modeled as the cross-sectional area of a backscatter equivalent sphere."* What is a backscatter equivalent sphere? The quantity *A* must be a geometric cross-sectional area of a particle regardless of their particle shapes, as both liquid and ice cases rely on Eq. (4) in deriving the backscattering coefficients from ECP data. As this is critical, please clarify and improve the inconsistency.

*The authors mean to indicate that an area-equivalent sphere is used to represent the size of the ice particle since Mie theory applies to spheres. To keep the text consistent the text has been updated with further details on how the cross-sectional area and diameter of an ice crystal are determined.*

***Changes:*** *Lines 255 – 258 have been updated to "For water spheres, $\pi r^2$ is the cross-sectional area (A), while for irregular particles such as ice, A is the cross-sectional area imaged by the two-dimensional probes (see the ice crystal image insert in Fig. 1). The cross-sectional area is converted to a diameter (or radius) by determining the sphere that has an equivalent, two-dimensional projected surface area to A.*

3. Figure 3 caption: "**A refractive index of 1.3263 + 5.6 x 10-7j**" To express the imaginary quantity, *i* should be used instead of *j*.

*This is correct, and the manuscript has been updated to use "i" to represent the imaginary quantity.*

***Changes:*** *Lines 265, 266, 297 and 298 have been updated to replace "1.3263 + 5.6 x 10-7j" with "1.3263 + 5.6 x 10-7i" and "1.3031 + 5.6 x $10^{-7}j$" "1.3031 + 5.6 x $10^{-7}i$".*