Response to Anonymous Referee #2

The research effort reported in the manuscript analyzed ice crystal images in mid-latitude cirrus clouds, towards developing internally consistent ice physical and optical properties for a size-resolved cloud microphysics model. Often reported in the literature, the parameterizations of ice cloud radiative properties and the counterparts of ice cloud microphysical properties are separately developed and thus lack internal consistency. The outcomes of this study represent an important contribution to a better understanding of ice cloud microphysical and radiative properties. Overall, the manuscript is well organized and clearly written. However, some improvements seem necessary before the manuscript is formally accepted for publication. Listed below are the reviewer's specific comments, which are mainly focused on the optical properties of ice crystals.

We appreciate the positive assessment and respond to comments below.

Several ice crystal habit models (specifically, a bucky ball model, an aggregate model, and a polycrystal model) are investigated in detail. For feasible light scattering calculation, ice crystal morphologies are highly simplified in comparison with realistic counterparts. A common justification for the simplifications is that the optical properties are realistic although ice crystal geometries are simplified and even unrealistic. An important constraint to check whether an ice crystal habit model is reasonable from the optical property perspective is to check the consistency of the corresponding optical properties between solar and infrared bands. The optical property parameterization in this study is largely based on Dr. van Diedenhoven's previous parameterizations. If the reviewer recollects correctly, Diedenhoven's previous parameterizations are developed for the solar bands, for example, van Diedenhoven et al. (2014a). Thus, it is suggested that the consistency of the present models between solar and infrared bands be validated. For the authors' information, a recent study in this regard has been reported: Holz, R.E., S. Platnick, K. Meyer, M. Vaughan, G. Wind, S. Dutcher, S. Ackerman, A. Heidinger, N. Amarasinghe, C. Wang, and P. Yang, "Resolving cirrus optical depth biases between CALIOP and MODIS using IR retrievals," Atmos. Chem. Phys. Discuss., 15, 29455-29495, doi:10.5194/acpd-15-29455-2015, 2015.

As infrared radiative transfer is dominated by emission, crystal shape has relatively little influence on it. In Holz et al. (2016 now in ACP) this fact is used to evaluate the applicability of assumed habit for shortwave retrievals. Holz et al. state that "because the sensitivity of IR IOT retrievals to ice crystal habit selection is minimal, these retrievals provide an independent means to evaluate the CALIOP and MODIS solar reflectance retrievals." Thus, an evaluation as presented by Holz et al. compares retrievals of optical thickness (and/or particle size) from both shortwave and IR measurements in order to evaluate of the optical model used for the shortwave. In contrast, our investigation aims to derive optical properties consistent with the in situ observations at various levels within cloud. Representative shortwave and IR measurements for the particular clouds under investigation do not exist and an evaluation as performed by Holz et al. therefore cannot be performed for these clouds. To clarify, we added the following text to line 28 on page 23: “Infrared radiative transfer is dominated by emission, which is affected by particle size, but its sensitivity to crystal shape is minimal (e.g., Holz et al. 2016). However, particle shape does affect the relevant shortwave optical properties substantially.”

The description of the optical property simulations requires clarification. For example, it is mentioned in the manuscript (the second paragraph on page 24) that the anomalous diffraction theory (ADT) was used to compute the extinction efficiency. However, ADT is not applicable to the phase function (thus, the asymmetry factor) computation. How is an asymmetry factor value that is consistent with the ADT simulation derived?

Since van Diedenhoven et al. (2014) is based on geometric optics calculations, it assumes extinction efficiency of 2 for all particles and wavelengths, and the anomalous diffraction was only used to partly correct this simplification for small particle sizes. Clarification added at page 24, line 13: “The van Diedenhoven et al. (2014) parameterization is based on geometric optics calculations. Accordingly, it assumes the extinction efficiency (Qe) to be 2 for all particles and wavelengths. To partly correct this simplification for small particle sizes, here we apply anomalous diffraction …”

On page 25 it is stated “a roughness parameter sigma as defined as Mack et al. (1996) …” (line 3) and “…we note that assuming plates with sigma=0.5…”. In addition, Yang et al. (2013) and Baum et al. (2014) are cited. In Mack et al. (1996), uniformly tilting of ice crystal facets is assumed whereas the Gaussian distribution is assumed in Yang et al. (2013) and Baum et al. (2014). It is explicitly mentioned “Since Baum et al. (2014) and van Diedenhoven et al. (2014b) show that a roughness parameter of 0.5 best fit observations…”. The same roughness parameter value (0.5) cannot be applied to the aforesaid two roughness definitions. Thus, it is suggested that an explicit definition of the roughness parameter be explicitly defined (maybe, an equation should be provided here). The clarification is important because the degree of surface roughness is a critical factor in determining the radiative forcing of ice clouds as illustrated by the following paper: Yi, B., P. Yang, B. A. Baum, T. L’Ecuyer, L. Oreopoulos, E. J. Mlawer, A. J. Heymsfield, K.-N. Liou, 2013: Influence of ice particle surface roughening on the global cloud radiative effect, J. Atmos. Sci., 70, 2794-2807.

Various definitions of the roughness parameters were compared by Neshyba et al. (2013) and by Geogdzhayev and van Diedenhoven (2016) and were found to be largely equivalent. This means that the same value of roughness parameter defined as by Macke et al. and that used by Baum et al. (2014) yields largely equivalent scattering properties. As demonstrated by Geogdzhayev and van Diedenhoven (2016), a roughness parameter of a given value but with different definitions represent very similar micro-structures on the crystal surfaces. As stated in the submitted manuscript (page 25, line 1): “In the van Diedenhoven et al. (2014a) parameterization, the level of surface distortion is specified by a roughness parameter δ as defined by Macke et al. (1996); differently defined roughness parameters are found to be roughly equivalent (Neshyba et al. , 2013; Geogdzhayev and van Diedenhoven, 2016).” This text is now extended to read:

“In the van Diedenhoven et al. (2014a) parameterization, the level of surface distortion is specified by a roughness parameter δ as defined by Macke et al. (1996). The Macke et al. (1996) ray-tracing code perturbs the normal of the crystal surface from its nominal orientation by an angle that, for each interaction with a ray, is varied randomly with uniform distribution between 0 and delta times 90°. Similar commonly used parameterizations of particle roughness perturb the crystal surfaces using Weibull (Shcherbakov et al. 2006) or Gaussian (Baum et al. 2014) statistics rather than uniform distributions. However, Neshyba et al. (2013) and Geogdzhayev and van Diedenhoven (2016) demonstrated that the same roughness parameter value defined through a Weibull, Gaussian or uniform distribution represents very similar crystal microscale surfaces and yields largely equivalent scattering properties.”

One page 4, acronyms SHEBA and ISDAC should be spelled out.

Now spelled out.

To resolve small sizes, it is suggested that logarithmic scale is applied to the maximum dimension in Figs. 15 and 22.

The choice of axes throughout is debatable. Here we prefer to use the same linear axis consistently across Figs. 14, 15, 22 and 23.