The authors would like to thank the reviewers for their excellent suggestions. A point-by-point response to the comments is provided below.

Reviewer 2:

Comments:

Lines 352-353: "The first period (7:45 – 8:12 UTC) depicted in Fig. 7a corresponds to the period we established had little to no liquid water and presented a high DWR slanted feature (referring back to Fig. 5)." I am not sure how this conclusion was made. The lidar observations in Fig. 5 indicates presence of two liquid layers at this time, which you point out on line 285. These layers are not very optically thin but may affect the attenuation.

> We have revised the text to address the reviewers concerns regarding a lack of clarity.
>
> "The first period (7:45 – 8:12 UTC) depicted in Fig. 7a corresponds to the period that presented a high DWR slanted feature (referring back to Fig. 5) and a thin liquid layer (referring back to the lidar backscatter observations of Fig. 4). Plotting the radar observations in DWR-DWR space can help determine if the amount of liquid attenuation caused by this thin liquid layer is significant thus preventing us for inferring particle habit directly from the gas attenuation corrected and calibrated radar measurements. To be exact, a clustering of the DWR-DWR observations collected in the upper part of the cloud (between 5.75-7.00 km) near the 0,0 point (depicted by the contours on Fig. 7a) would indicate an absence of signal attenuation. For this particular period, a 0.5 dB offset is seen suggesting that a slight adjustment should be made to the observed DWR before they can be interpreted in terms of differential scattering and used to infer particle habit."

Line 358: "This suggests that the particles observed are not represented the scattering libraries used and calls for further research." This conclusion is not necessarily correct. The PSD of snow aggregates tend to be super exponential (Westbrook et al. 2004), i.e. the shape parameter is negative. The super exponential PSD will push the triple frequency curve to the left (Mason et al. 2019), so even for the given scattering models you may be able to reproduce the observations.

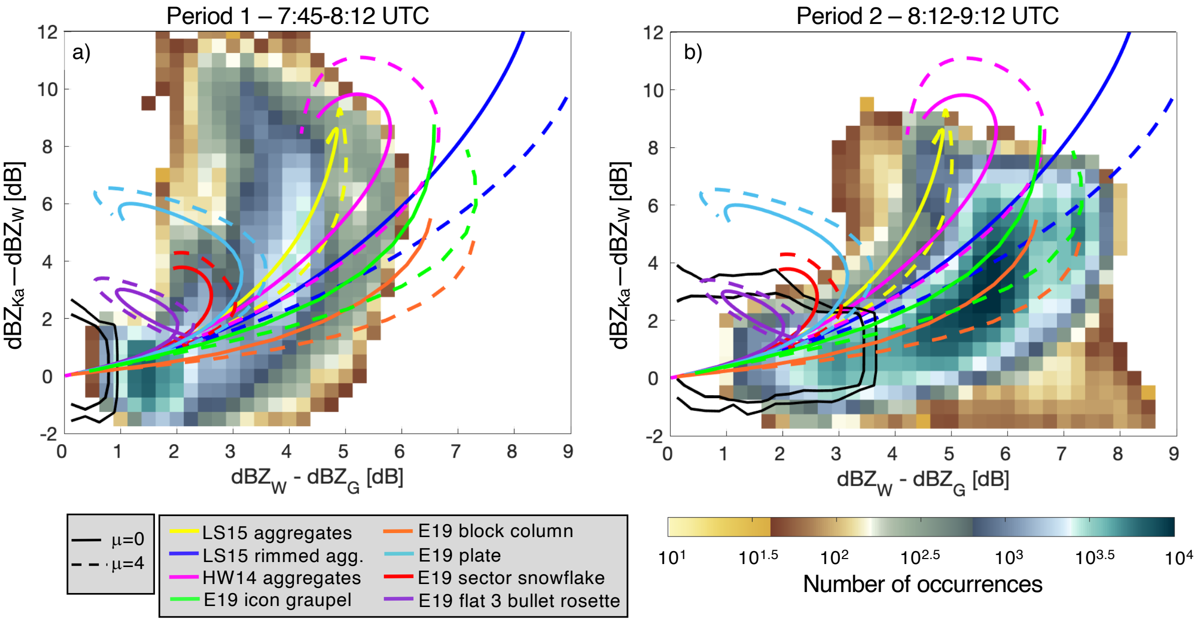
Westbrook, C. D., Ball, R. C., Field, P. R., and Heymsfield, A. J. (2004), Universality in snowflake aggregation, Geophys. Res. Lett., 31, L15104, doi:10.1029/2004GL020363.

Mason, S. L., Hogan, R. J., Westbrook, C. D., Kneifel, S., Moisseev, D., and von Terzi, L., 2019: The importance of particle size distribution and internal structure for triple-frequency radar retrievals of the morphology of snow, Atmos. Meas. Tech., 12, 4993– 5018, https://doi.org/10.5194/amt-12-4993-2019, 2019

> We agree with the reviewer that our original statement was too definitive and modified the text to acknowledge that other factors would need to be explored to get a more comprehensive picture of the accuracy of all existing scattering libraries. We also now include scattering calculations made using the Discrete Diploe Approximation to provide a perspective other than the self-similar-Rayleigh-Gans approximation.

“Overlaid are DWR$_{Ka\text{-}W}$-DWR$_{W\text{-}G}$ estimated using self-similar-Rayleigh-Gans approximation and different particle type models and PSD; specifically, unrimed aggregates are represented using the mass-diameter relationships from Hogan and Westbrook (2014) (hereafter HW14) and that of Leinonen and Szyrmer (2015) (hereafter LS15) particle class A. Rimed aggregates are represented using the mass-diameter relationships of LS15 for particle type B with 2 kg m^{-2} of liquid water path. Also overlaid are DWR$_{Ka\text{-}W}$-DWR$_{W\text{-}G}$ estimated using Discrete Dipole Approximation scattering calculations for different particle types following formulation prepared by Eriksson et al., (2018) (hereafter E19); specifically: icon graupel, block column, plate, sector snowflake and flat three bullet rosette. Since the shape of the PSD may also impact the scattering of the ice crystal population, PSDs are represented using a gamma function with a shape parameter (μ) of either 0 or 4. We acknowledge that this does not encompass all PSD shapes such as the super exponential one of aggregate populations reported by Westbrook et al. (2004). In any case, the idea is to use overlap between the observed and estimated DWR-DWR to gain information about particle habit.

The first period (7:45 – 8:12 UTC) depicted in Fig. 7a corresponds to the period that presented a high DWR slanted feature (referring back to Fig. 5) and a thin liquid layer (referring back to the lidar backscatter observations of Fig. 4). Plotting the radar observations in DWR-DWR space can help determine if the amount of liquid attenuation caused by this thin liquid layer is significant thus preventing us for inferring particle habit directly from the gas attenuation corrected and calibrated radar measurements. To be exact, a clustering of the DWR-DWR observations collected in the upper part of the cloud (between 5.75-7.00 km) near the 0,0 point (depicted by the contours on Fig. 7a) would indicate an absence of signal attenuation. For this particular period, a 0.5 dB offset is seen suggesting that a slight adjustment should be made to the observed DWR before they can be interpreted in terms of differential scattering and used to infer particle habit. Even with this slight adjustment, we find that the scattering calculation results only partially match the DWR-DWR signatures observed leaving a noticeable gap in the high (> 7 dB) DWR$_{Ka\text{-}W}$ and low (< 5 dB) DWR$_{W\text{-}G}$ region. This gap could result from outstanding radar calibration bias or from a misrepresentation of the particle size distribution and/or shape of naturally occurring ice crystal in existing scattering libraries. In any case, it calls for further research. We note that the scattering models that are closest to the observed values are those for unrimed aggregates (yellow and magenta lines) and plates (cyan line).”



"Figure 7: For observations collected a) between 7:45–8:12 UTC and b) between 8:12–9:12 UTC; distribution of Ka-W dual-wavelength ratio as a function of W-G dual-wavelength ratio for the cloud region between 2 and 5.5 km altitude (colormap) and for the cloud region between 5.75 and 7 km altitude (contours). Lines represent effective reflectivity calculated using scattering models with different particle type (colors) and with different particle size distribution shape parameter (line type). More details about these scattering models are given in the text."

Lines 399-401: "In the non-Rayleigh scattering regime, σ_b does not monotonically in- crease with D^6 but rather follows a lower power of quasi-periodic form with exponential damping of the oscillation (Fig. 4 of Kollias et al., (2007a))." Are you describing the resonance scattering regime, or as sometime referred to as Mie scattering? If yes, just say that.

The reviewer is correct. The sentence was rephased to improve the reference to this known scattering behavior.

"In the non-Rayleigh scattering regime, σ_b does not monotonically increase with D^6 but rather follows a lower power resonance pattern with damping of the oscillation (Fig. 4 of Kollias et al., (2007a))."

Line 405: The sentence starting as "Previous work has associated the top boundary..." is, in my opinion too long, and a bit difficult to follow. It would help if you could simplify it. There are several new studies discussing how ML boundaries depend on radar frequency:

Li, H., and D. Moisseev, 2020: Two layers of melting ice particles within a single radar bright band: Interpretation and implications. Geophys. Res. Lett., 47, e2020GL087499. https://doi.org/10.1029/2020GL087499

And how ML radar signatures at different wavelengths depend on snow properties:

Li, H., Tiira, J., von Lerber, A., and Moisseev, D., 2020: Towards the connection be- tween snow microphysics and melting layer: insights from multifrequency and dual- polarization radar observations during BAECC, Atmos. Chem. Phys., 20, 9547–9562, https://doi.org/10.5194/acp-20-9547-2020.

We would like to thank the reviewer for bringing to our attention these two very recent publications. Upon reading these 2 articles we have revised our discussion of the bright band signature.

"Inferring information about the ice melting process from the properties of the radar-detected bright band is still an active area of research (e.g., Heymsfield et al., 2015;Li et al., 2020). The early work of Fabry and Zawadzki (1995) suggested that the magnitude and vertical extent of the radar reflectivity enhancement at cm-wavelength are influenced by precipitation rate, phase transitions (i.e., liquid coating ice), change in fall speed throughout melting, precipitation growth and changes in the particle size distribution linked to aggregation and breakup. More recent studies using cm-wavelength radars suggested that the depth of the radar bright band, at cm-wavelengths, may be linked to the presence of rimed particles (e.g., Kumjian et al., 2016;Wolfensberger et al., 2016). In contrast, at mm-wavelength radars, non-Rayleigh scattering reduces the influence of large melting snowflakes in determining the magnitude and vertical extent of the melting layer radar signature (Kollias and Albrecht, 2005). In addition, due to their increased relative sensitivity to small melting ice crystals, millimiter-wavelength radars like KASPR and ROGER observe a higher top boundary of their bright band. While not observed here, it has been suggested that W-band radars can provide insight into the activity of the aggregation process because this process is believed to cause of a dip, as opposed to the enhancement that is the bright band, in the radar reflectivity profile (a.k.a. dark band; (Sassen et al., 2005;Sassen et al., 2007;Heymsfield et al., 2008)). Interestingly, observations collected by the VIPR reveal a well-defined bright band at G-band frequency. VIPR's bright band differs from that of the other radars in two main ways: 1- its top boundary is slightly higher compared to that of the W-band, 2- its bottom boundary is higher than that of the X-band. These discrepancies are in line with our interpretation that VIPR's signal is controlled by the melting of even smaller ice crystals. This agrees with Li and Moisseev (2020) interpretation that the radar bright band properties depend on the radar wavelength since the radar wavelength effectively dictates the ice population size "in focus"."

Line 433: "The other fact that SKYLER could also not observe the cloud top also speaks to the importance of operating sensitive X-band radars for cloud studies (liquid attenuation not being an issue at X-band)." You may want to generalize this statement to cm-wavelength (i.e. Ku-band or C-band) radars that are not suffering from significant attenuation as well.

Good suggestion by the reviewer. The sentence was revised accordingly.

"The other fact that SKYLER could also not observe the cloud top also speaks to the importance of operating sensitive X-band radars for cloud studies (liquid attenuation not being an issue at cm wavelengths)."

Conclusions:

Line 459, point 2: While I agree with this conclusion, I miss a discussion in the results section that supports this conclusion. If it is not there, you may want to include it.

This conclusion emerged from our gas attenuation correction activity described in Sec. 3.1 and presented below for reference.

"For this particular mid-latitudinal winter case, we estimate two-way gas attenuation at 11 km to reach ~0.1 dB at X-band, ~0.5 dB at Ka-band, ~2.0 dB at W-band and 10.0 dB at G-band. The large variability in gas attenuation from frequency to frequency, especially near water vapor absorption lines, is what allows DAR techniques to be used for water vapor profiling. On the upside, the notable magnitude of the gas attenuation at higher-frequencies (i.e., W-band but even more so G-band) makes them ideal frequencies to use for such application. On the downside, significant gas attenuation hinders the sensitivity of high frequency radars to clouds and light precipitation."

Line 466, point 3: While high sensitivity is important and you demonstrate that it is possible to achieve it, whether the Rayleigh plateau will be reached will also depends on attenuation. Therefore, it would limit this application to relatively optically thin clouds. The -20 dBZ requirement, as far as I remember, originates from one of Hogan's studies and is referring to unattenuated reflectivity. You should point it out in the discussion.

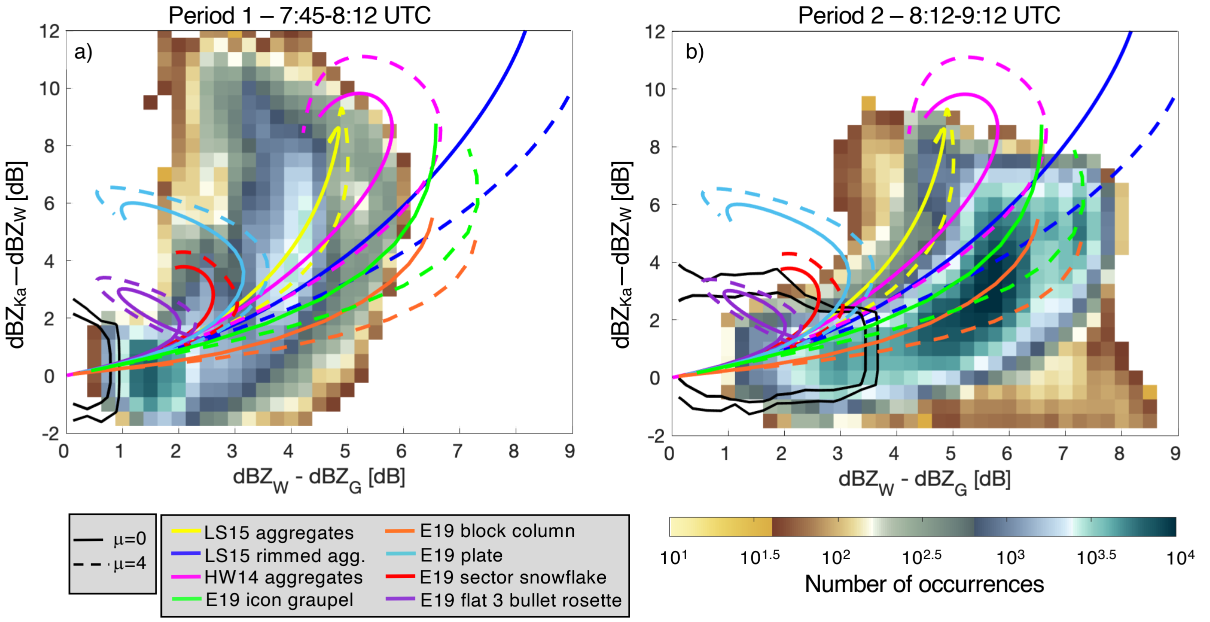
The reviewer makes a very good point. The discussion related to point 3 was expanded to touch on this important point.

"Nominally radar systems should be capable of detecting unattenuated reflectivity as weak as -40 dBZ at 1 km after 1-s signal integration (i.e., -20 dBZ at 10 km altitude). In the present study, the radars deployed generally meet this sensitivity criteria. It follows that deployments in humid environments would drive higher sensitivity requirements because of enhanced signal attenuation by water vapor. The same can be said about deployments in liquid containing clouds where enhanced signal attenuation by liquid water is to be expected."

Line 487, point 7: I think this conclusion is not well supported. In addition to what I said above, you only have tested one single scattering library.

Again, we agree with the reviewer that our original statement was too definitive and modified the text to acknowledge that other factors would need to be explored to get a more comprehensive picture of the accuracy of all existing scattering libraries. We also now include scattering calculations made using the Discrete Diploe Approximation to provide a perspective other than the self-similar-Rayleigh-Gans approximation.

“The scattering libraries tested could only provide a partial explanation of the scattering properties of the ice crystals observed with gaps in the high (> 7dB) $\mathrm{DWR}_{\mathrm{Ka\text{-}W}}$ and low (< 5 dB) $\mathrm{DWR}_{\mathrm{W\text{-}G}}$ region. This gap could result from outstanding radar calibration bias, or from a misrepresentation of the particle size distribution and/or shape of naturally occurring ice crystal; in any case additional triple frequency observations including G-band would help confirm this finding, which, if correct, should motivate further research into the scattering properties of naturally occurring ice crystal populations.”



“Figure 7: For observations collected a) between 7:45–8:12 UTC and b) between 8:12–9:12 UTC; distribution of Ka-W dual-wavelength ratio as a function of W-G dual-wavelength ratio for the cloud region between 2 and 5.5 km altitude (colormap) and for the cloud region between 5.75 and 7 km altitude (contours). Lines represent effective reflectivity calculated using scattering models with different particle type (colors) and with different particle size distribution shape parameter (line type). More details about these scattering models are given in the text.”