A Case Study of an Arctic Mixed-Phase Cloud with Riming and Aggregation of Dendrites Using KAZR, Ka-SACR2 and Multi-Angle Snowflake Camera (MASC)

Zhiyuan Jiang[1], Johannes Verlinde[1], Kultegin Aydin[2], and Matthew R. Kumjian[1]
[1]Department of Meteorology and Atmospheric Science, The Pennsylvania State University
[2]Department of Electrical Engineering, The Pennsylvania State University

PennState

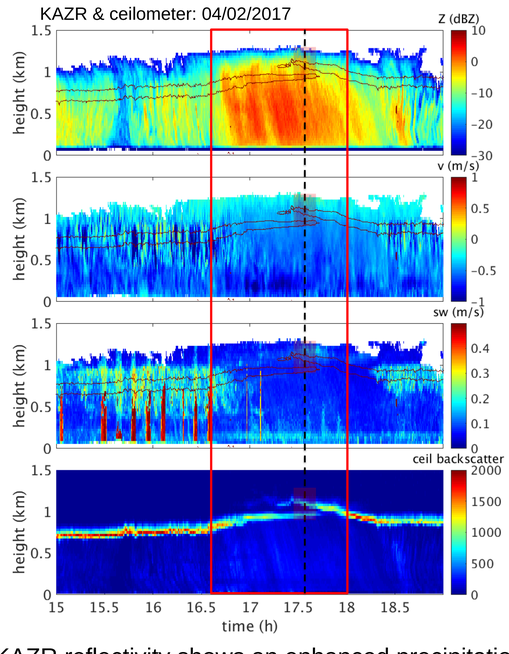
1. Introduction

- Riming and aggregation are two different ice microphysical processes, but with similar radar fingerprints;
- Majority of clouds in Arctic is mixed-phase clouds, where riming and aggregation can both occur;
- Documentation of cases of riming and aggregation with collocated radar observations can help to identify the difference between the two processes.

2. Objective

- Investigate the microphysical processes in a case of Arctic mixed-phase clouds with radar observations and multi-angle snowflake camera (MASC);
- Compare the polarimetric radar signatures of observations with scattering calculations of rimed dendrites and aggregates.

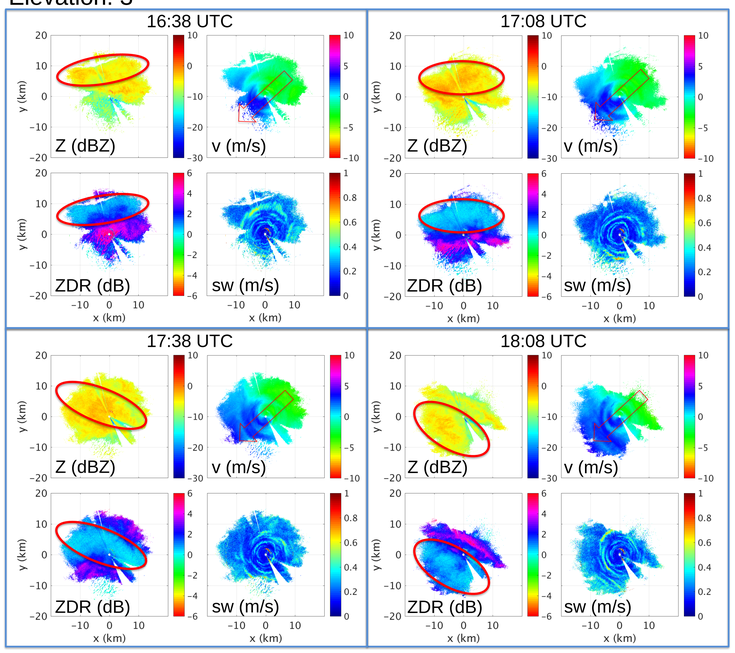
3. KAZR & Ceil



KAZR reflectivity shows an enhanced precipitation event lasting from 16:40 UTC till about 18 UTC. Ceilometer reveals multiple super-cooled liquid layers exist during the heavy precipitation period.

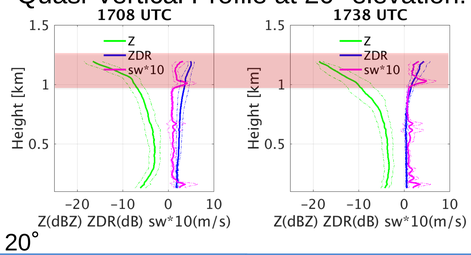
4. Ka-SACR2 & MASC

Elevation: 3°

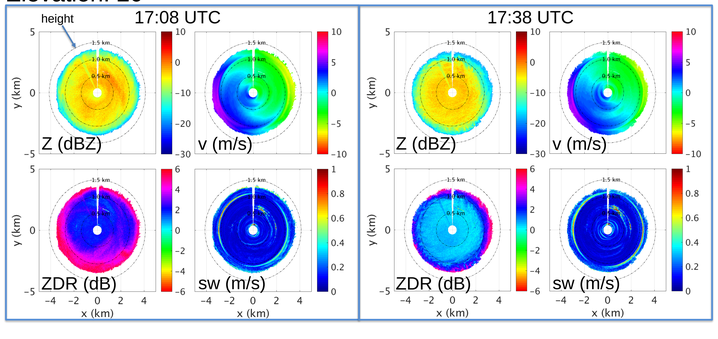


Ka-SACR2 3° elevation PPI sequence (above) reveals low ZDR (0-1dB) associated with the heavier precipitation passing over radar from the northeast, compared to surrounding precipitation where higher ZDR (>4dB) was measured.

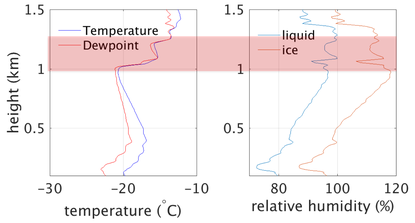
Quasi-Vertical Profile at 20° elevation:



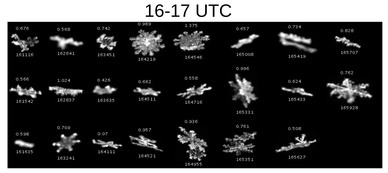
Elevation: 20°



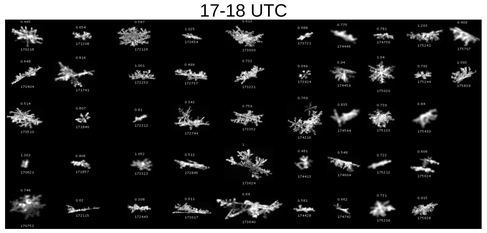
Sounding at 17:38 UTC



16-17 UTC



17-18 UTC

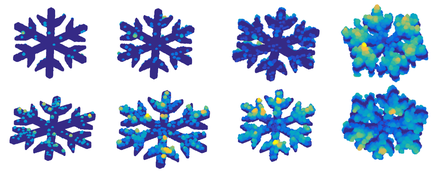


The sounding (top panel) shows that planar crystals were favored to be generated during this precipitation event, with some degree of riming due to the existence of super-cooled liquid layers below the genesis region. This agrees with the MASC observations (above). The MASC indicates that riming, with almost no aggregation, dominated prior to 17 UTC, whereas some degree of aggregation appears after 17 UTC in the heavier precipitation.

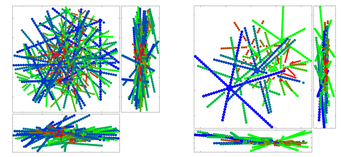
The Ka-SACR2 20° elevation PPI scans (left) are azimuthally symmetric, allowing use of quasi-vertical profiles (QVP) to investigate the microphysical processes. At 17:08 UTC, ZDR decreases from 5dB at 1.2km to 2-3dB near the surface. Dendrites were generated aloft, and rimed while falling through liquid layers. The signature agrees well with scattering calculations of rimed dendrites. At 17:38 UTC, ZDR decreases to values below 1dB. This is consistent with the lower ZDR from scattering calculation for the aggregates.

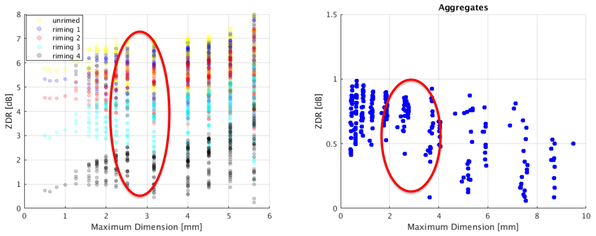
5. Scattering

Rimed dendrites: Degree of riming: 1 2 3 4



Aggregates (Lu et al., 2016):





Scattering calculations of rimed dendrites and aggregates. Unrimed dendrites have ZDR values between 4 and 7 dB decreasing to 2-3 dB with riming degree between 3 and 4. This matches with the QVP of ZDR at 17:08 UTC. Aggregates have ZDR values between 0 and 1 dB. This corresponds with the QVP at 17:38 UTC, indicating the presence of aggregates.

6. Summary

- An Arctic mixed-phase cloud with riming and aggregation of dendrites is studied with the synergy of zenith-pointing and scanning Ka-band radars, multi-angle snowflake camera, and theoretical scattering calculations of rimed dendrites and aggregates.
- A persistent super-cooled liquid layer existed in light ice precipitation between 0.7 – 1.0 km. Prior 17 UTC riming of dendrites dominated with little aggregation. ZDR decreases from 5dB to 2-3dB, which agrees with the scattering calculation of rimed dendrites.
- Between 17-18 UTC aggregates formed because more ice crystals were generated. ZDR drops below 1dB. This agrees with the scattering calculation of aggregates.

References

Lu et al., 2016. A polarimetric scattering database for non-spherical ice particles at microwave wavelengths. *Atmospheric Measurement Techniques*, *9*(10), pp.5119-5134.

Acknowledgments

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