The Influence of Winter Storm Conditions on Observed Ice Crystal Characteristics

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Motivation/Background

Current numerical weather models often have high uncertainty when predicting winter storm snowfall rates. We investigate the atmospheric conditions that precipitation-sized particles (greater than 0.2 mm in diameter) experience during their lifetime falling through a cloud.

Riming—a fast mode of ice growth within a storm—is the process of supercooled water droplets colliding with and freezing on contact to precipitation-sized ice particles at temperatures between −40 and 0 °C. As the snow particles fall and move horizontally within a cloud, they may collect droplets yielding various degrees of riming.

Data and Methods

To determine combinations of features of the storm environment that influence the degree of riming, we analyze snow particle characteristics in the context of overall storm structure observed by airborne radars. We analyze data from two research aircraft deployed during NASA's Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) 2020-2023 campaign. The NASA ER-2 aircraft flies above cloud top with downward pointing instruments including the Cloud Radar System (CRS) that provides a vertical profile of the structure of the storm. Flying below the ER-2 through the storm is the P-3 aircraft that takes measurements with instruments including the 2D-S Stereo Probe that measures particle concentration, and the Turbulent Air Motion Measurement System (TAMMS) used to measure vertical air motion. We also use high-resolution images of snow particles obtained from the Particle Habit Imaging and Polar Scattering (PHIPS) probe aboard the NASA P-3 aircraft to categorize the amount of riming present on ice crystals in various flight legs from multiple winter storms. Magenta scale bar on ice particle images = 500 micrometers, which is about 2/3 of the thickness of a credit card.

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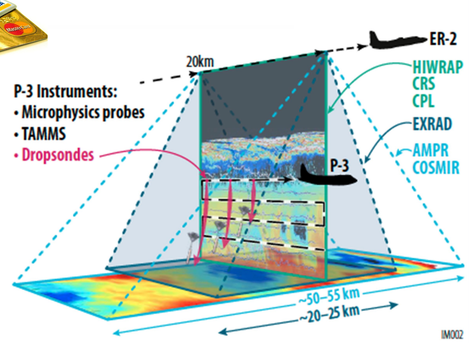
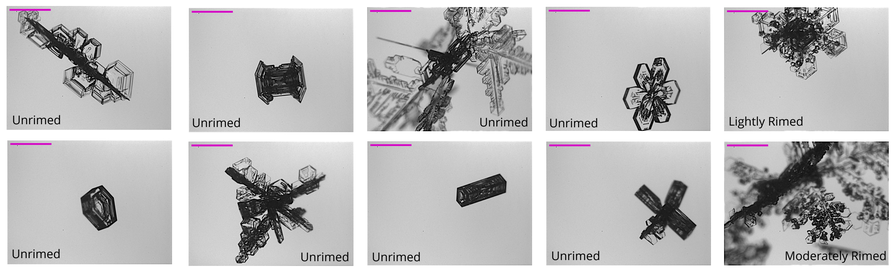
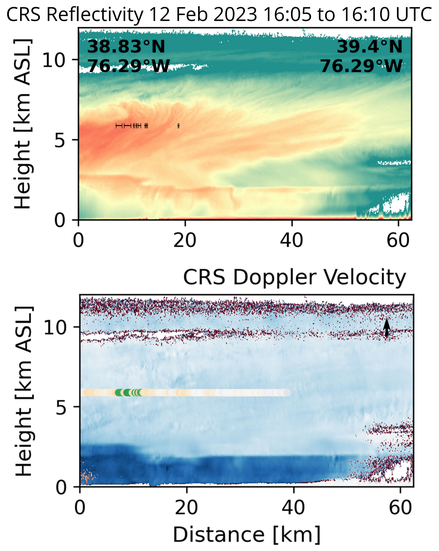


Low Riming Flight Leg
20230212 – 16:05:19 to 16:10:22 UTC

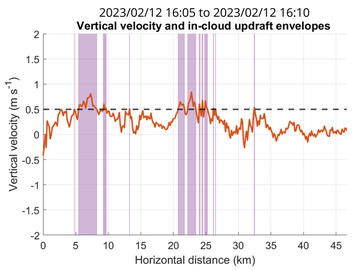


Examples of PHIPS ice crystal images with and without riming. Rimed ice crystals represented less than ~20% of PHIPS images along the flight track. Magenta scale bar on ice particle images = 500 micrometers.



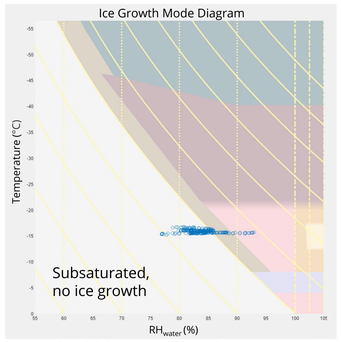
ER-2 CRS radar reflectivity data with the P-3 flight track overlaid as black horizontal lines bounded by vertical bars where TAMMS vertical velocity ≥ 0.5 m s^{-1} (top). CRS Doppler velocity with the P-3 flight track overlaid with colored points showing TAMMS vertical velocity (bottom).

This flight leg went through areas of higher reflectivity ranging up to about 15 dBZ and a near steady vertical velocity. This indicates moderately large and heavy particles within the cloud.



TAMMS vertical velocity (orange) with in-cloud updraft envelopes (purple) and updraft threshold as horizontal dashed line (left). Time is converted to distance traveled by the aircraft.

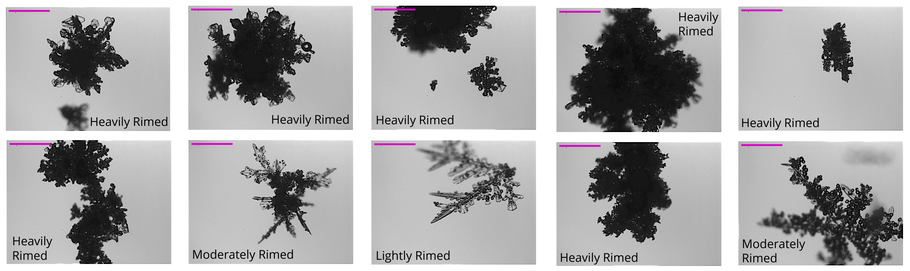
This flight leg had wide updraft envelopes where the vertical velocity was ≥ 0.5 m s^{-1}. TAMMS vertical air velocity ranged from -0.5 m s^{-1} to 0.75 m s^{-1} where positive values represent upwards motion.



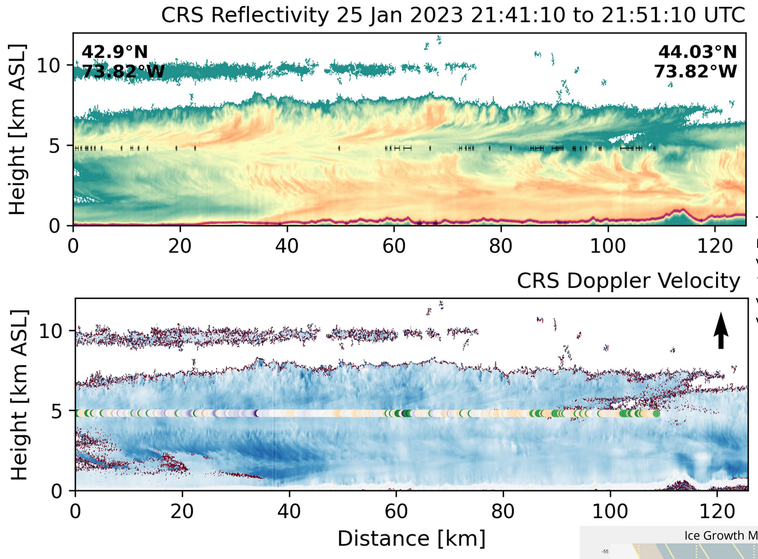
Environment of PHIPS images (blue circles) along flight track plotted on a RH_{water} (%) vs. Temperature (°C) graph with yellow contours of RH_{ice} (%) overlaid (above).

Majority of crystals in area of RH_{water} and RH_{ice} < 100% where ice sublimates and liquid evaporates yielding no ice growth.

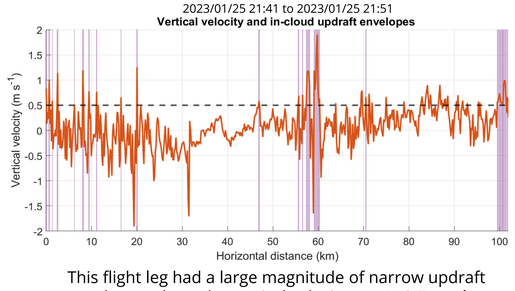
High Riming Flight Leg
20230125 – 21:41:10 to 21:51:10 UTC



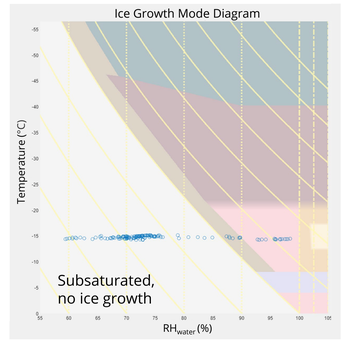
Examples of PHIPS ice crystal images along the flight track with varying degrees of riming including some heavily rimed particles with a thick coating of rime. Magenta scale bar on ice particle images = 500 micrometers.



This flight leg measured reflectivity values of about -5 to 10 dBZ and had varying velocity values.



This flight leg had a large magnitude of narrow updraft envelopes where the vertical velocity was ≥ 0.5 m s^{-1}. TAMMS vertical air velocity ranged from about -2 m s^{-1} to 2 m s^{-1} where positive values represent upwards motion.



Majority of crystals in area of RH_{water} and RH_{ice} < 100% where ice sublimates and liquid evaporates yielding no ice growth.

Summary and Future Work

Our preliminary investigation of two NASA IMPACTS flight legs from different days found that the low riming leg had higher reflectivities and wider updraft envelopes. In contrast, the high riming leg had more variation in vertical velocity and a large magnitude of smaller updraft envelopes. Both flights observed ice crystals in a subsaturated environment with temperatures between -14 and -18 °C but the high riming leg experienced a wider range of RH_{water}.

In the future, we will expand our dataset by looking at other NASA IMPACTS flight legs from 2020-2023 to compare the influence of varying atmospheric conditions and storm structures on ice crystal characteristics.

Acknowledgements

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Reference

NASA IMPACTS
https://espo.nasa.gov/impacts/content/IMPACTS