Airborne Observations of Environments for Ice Growth and Shrinkage in Winter and Summer Storms

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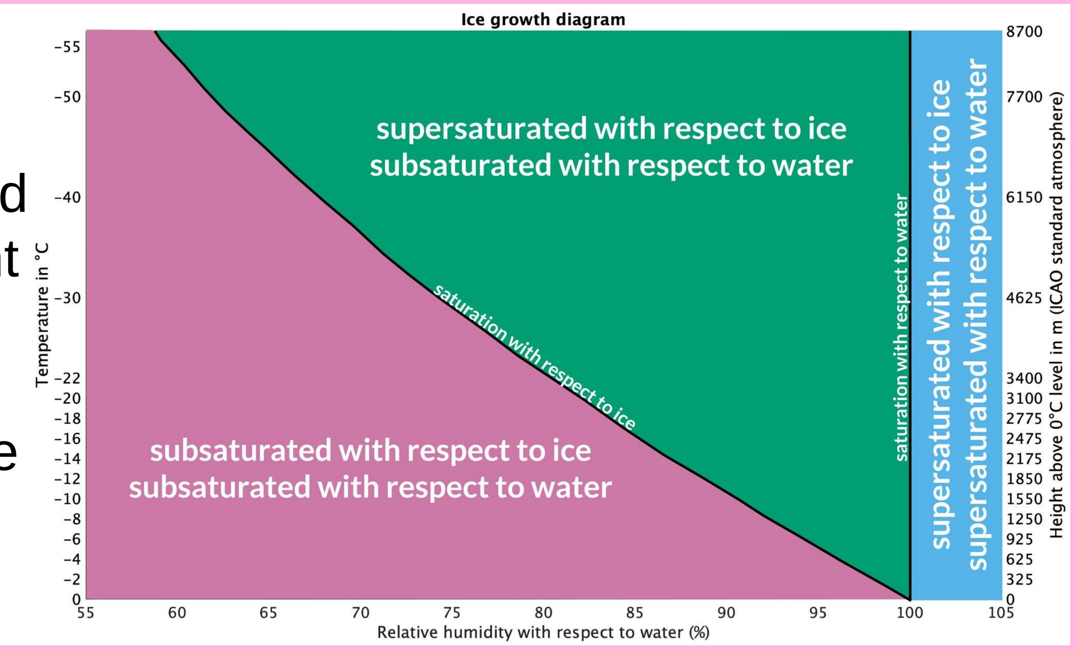
Motivation

Sets of precipitation-size (≥ 0.2 mm diameter) ice particles can increase in mass per unit volume by vapor deposition and riming, and can decrease in mass through sublimation depending on the ambient humidity, which is controlled by factors including vertical air motions, air temperature, and cloud water and moisture transport[1]. Enhanced understanding of where ice mass increases and decreases within the storm volume will aid in understanding the relative roles of different physical processes controlling surface precipitation.



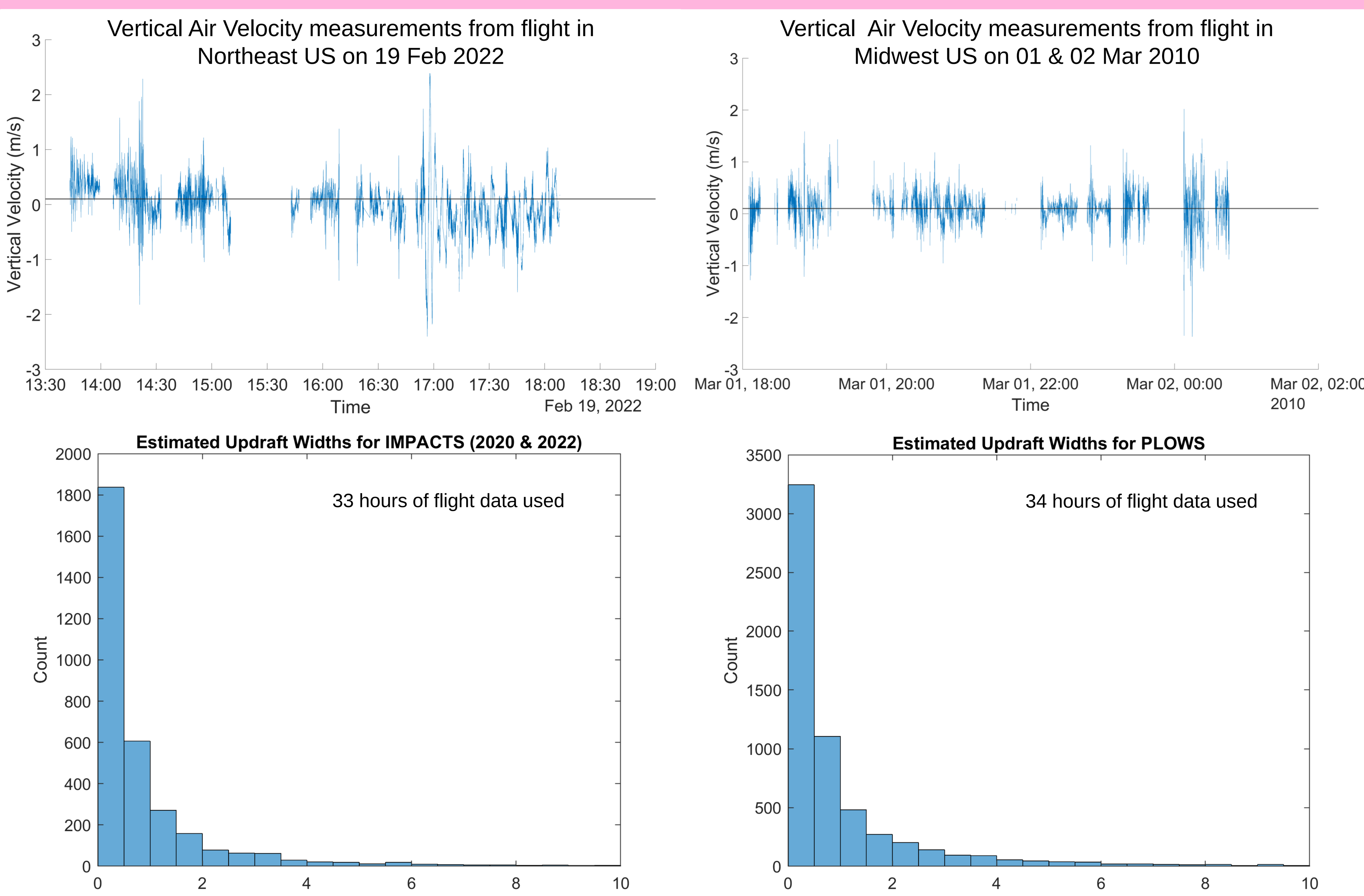
Project	Weather/Cloud types sampled	Instrument for cloud sensing	Diameter Range of Sampled Particles (μm)
ICE-T	Subtropical marine cumulus	2D-C	75-1450
PLOWS	Midwest US winter storms	2D-C	75-1200
IMPACTS	Northeast coast and Midwest US winter storms	2D-S	30-1900

Methods

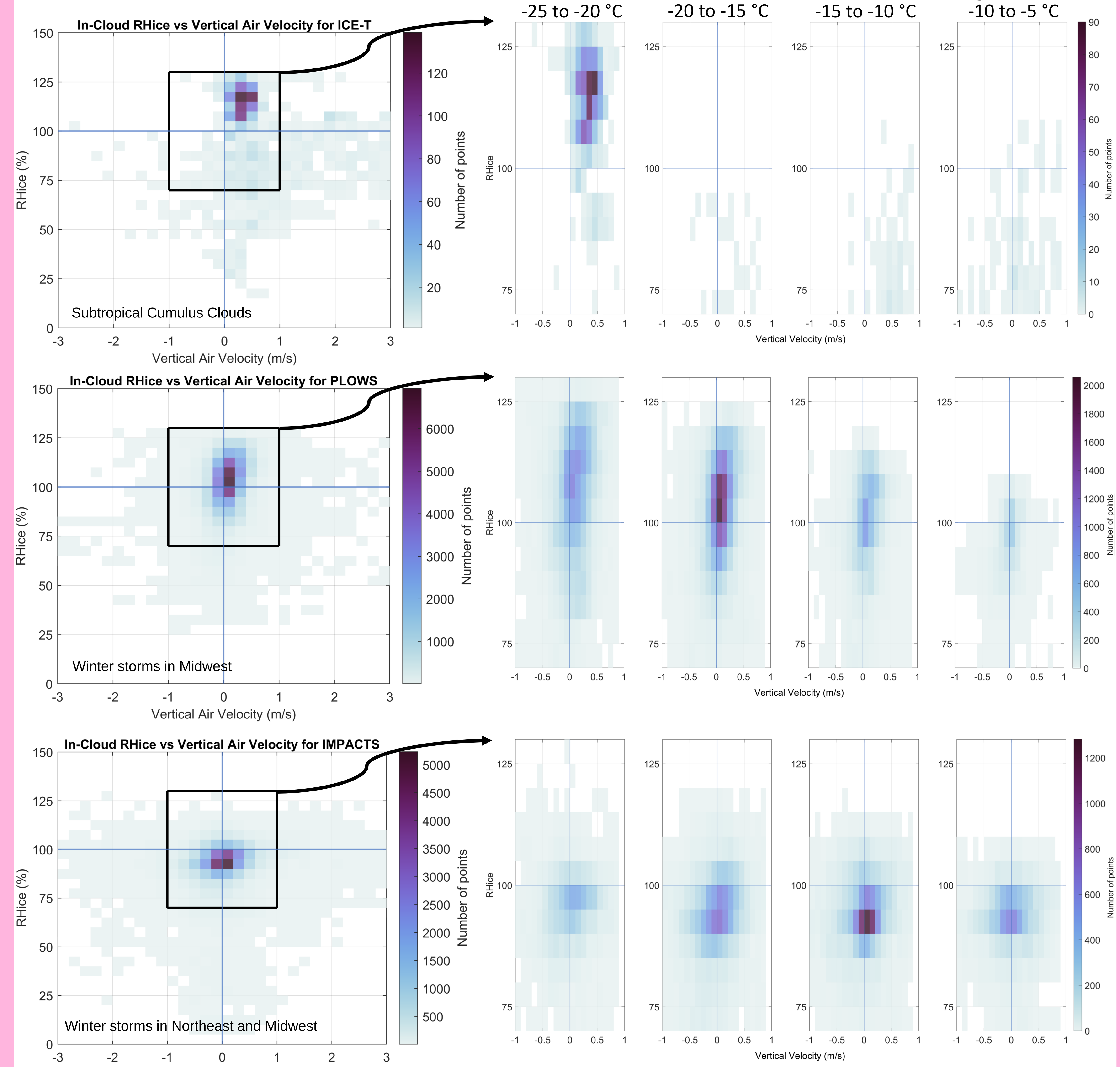
We examine in situ aircraft measurements from NASA's Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS)[2] as well as NSF's Profiling of Winter Storms (PLOWS)[3] and Ice in Clouds Experiment-Tropical (ICE-T)[4]. Measurements are filtered to examine only in-cloud points, which are defined as any point that had a cloud particle concentration greater than zero. Updraft widths are calculated from flight level data for contiguous periods with w > 0.1 m/s.

Updraft Width Estimates in Winter Storms

(top row) Examples of flight level timeseries of 1 Hz vertical air velocity measurements and (bottom row) histograms of approximate horizontal updraft widths for IMPACTS and PLOWS. The horizontal line in the timeseries plots indicates 0.1 m/s, the designated threshold for an updraft. Air speed is used to convert from time to distance. All in-cloud periods during all available flights are included in the updraft width histograms.

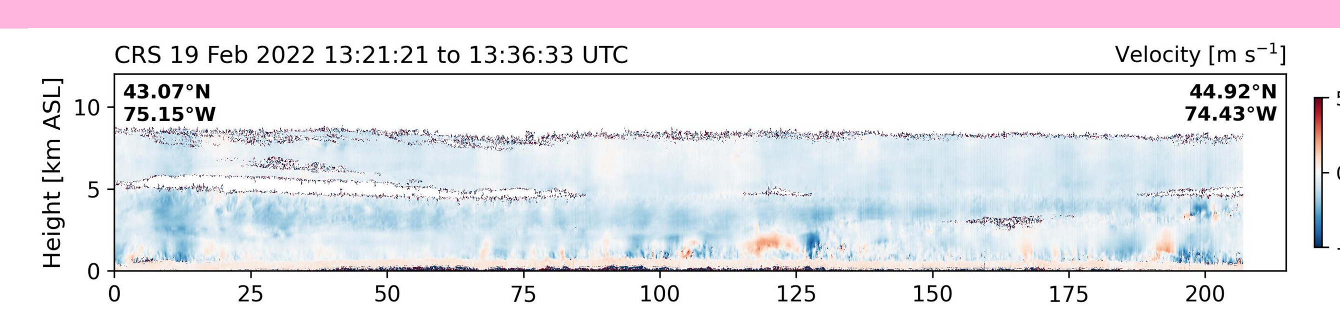


Joint Distributions, RHice versus Vertical Air Velocity



Left side includes all points within ± 3 m/s and -25 to -5 °C, right side focuses on ± 1 m/s and is subdivided based on temperature ranges (listed above top row).

Doppler Velocity Patterns



Doppler Velocity data along flight track obtained by NASA ER-2's vertically-pointing Cloud Radar (CRS)

Summary

- The distributions of updraft widths are highly skewed and most individual updrafts are less than 500 m wide in data from both winter projects.
- As expected, the subtropical cumulus sampled during ICE-T are biased toward weakly positive vertical velocity values. In contrast, the vertical air motions in PLOWS and IMPACTS are centered near 0 m/s. Vertical air motions with magnitudes > 1 m/s are rare in all three projects.
- Future work will examine whether the dryer environments observed in winter storms from IMPACTS compared to PLOWS are an instrument issue or a common physical feature of the storms and will integrate the P-3 flight level vertical velocity with the broader spatial view of vertical velocity from ER-2 airborne Doppler radars.

Acknowledgements

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References

[1]Hueholt et al. (2022, BAMS)
[2]McMurdie et al. (2022, BAMS)
[3]https://www.eol.ucar.edu/field_projects/plows
[4]https://www.eol.ucar.edu/field_projects/ice-t