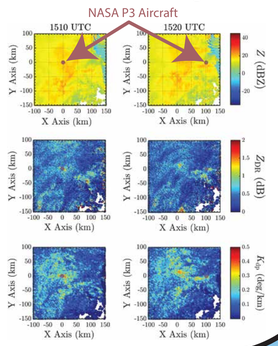
Radar Retrieval Evaluation and Investigation of Dendritic Growth Layer Polarimetric Signatures in a Winter Storm

Edwin L. Dunnavan[1,2], Jacob T. Carlin[1,2], Jiaxi Hu[1,2], Petar Bukovcic[1,2], Alexander Ryzhkov[1,2], Peter A. Brechner[1,3], Greg M. McFarquhar[1,3], Joseph A. Finlon[4], Sergey Matrosov[5]

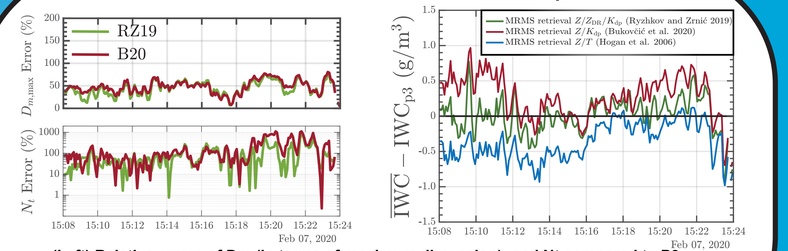
[1] Cooperative Institute for Mesoscale Meteorological Studies/University of Oklahoma (CIMMS/OU)
[2] NOAA/OAR National Severe Storms Laboratory (NSSL)
[3] School of Meteorology, University of Oklahoma (OU)
[4] Department of Atmospheric Sciences, University of Washington
[5] Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder

Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) Campaign

- Observations were taken from **Feb. 7th, 2020 in upstate NY** during the IMPACTS field campaign.
- NASA P3 aircraft took measurements within the **Dendritic Growth Layer (DGL).**
- In situ measurements were obtained for **Ice Mean Volume Diameter (Dm)**, **Ice Number Concentration (Nt)** and **Ice Water Content (IWC).**
- Radar retrievals were performed along the P3 flight path and compared to the in situ measurements.
- Polarimetric radar enhacement regions of differential reflectivity (ZDR), specific differential phase (KDP), and a proxy for circular depolarization ratio (CDRp) were observed at two separate time periods 10 minutes apart.
- These enhancement regions are quite small **(~ 10 km²)**, yet the NASA P3 aircraft flew through each region at approximately **5.0 km ASL** (see figure).



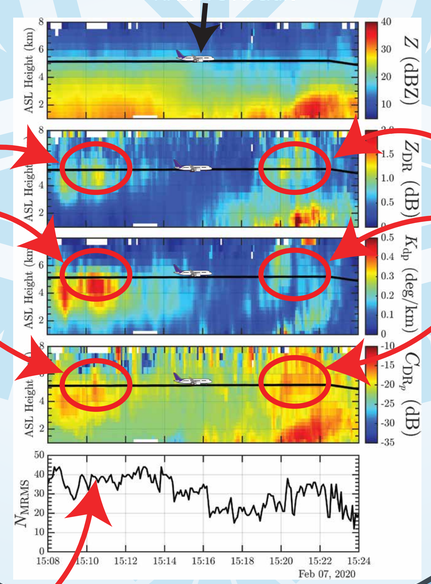
MRMS Radar Retrieval and In Situ Comparison



- **(Left) Relative errors of Dm (in terms of maximum dimension), and Nt compared to P3 probe observations.**
- **(Right) Absolute errors of IWC for (RZ19), (B20), and the IWC(Z,Temp) approach of Hogan et al. (2006) (H06).**

What causes these DGL polarimetric signatures?

How accurate are polarimetric radar retrievals inside and outside these regions?



1508 — 1512 UTC
First Enhancement Region

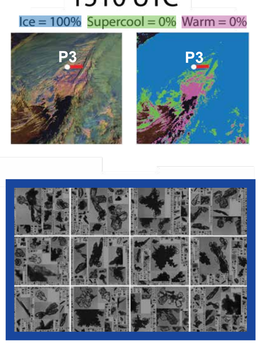
1520 — 1521 UTC
Second Enhancement Region

1510 UTC

- **(Top) Satellite retrievals for 1510 UTC.**

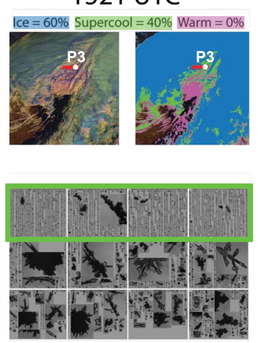
  (Left) RGB maps. (Right) cloud-top phase.

- **(Bottom) CPI images from P3 aircraft.**



Wide variety of dry ice particles

1521 UTC



- **(Top) Satellite retrievals for 1521 UTC.**

  (Left) RGB maps. (Right) cloud-top phase.

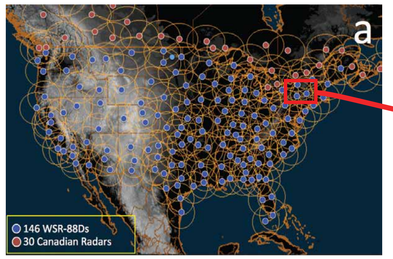
- **(Bottom) CPI images from P3 aircraft.**

Significant number of supercooled liquid droplets

The Multi-Radar/Multi-Sensor (MRMS) system

- MRMS is a National Severe Storms Laboratory (NSSL) developed system.
- Polarimetric radar variables from **176 NEXRAD radar sites** are mapped onto a common 3D grid.
- Approximately **1.1 km horizontal resolution** with **33 nonlinearly spaced vertical levels.**
- Time resolution is **10 minutes.**
- Collocation of MRMS polarimetric variables with the P3 in situ aircraft data is performed through bootstrapping (i.e., sampling with replacement) MRMS grid points.
- Each set of collocated Z, ZDR, and KDP is then used to retrieve Dm, Nt, and IWC following the retrieval methodologies of Ryzhkov and Zrnic (2019) (RZ19) and Bukovcic et al. (2020) **(B20).**

Figure adapted from Figure 1 of Zhang et al. 2016



Number of unique bootstrap MRMS grid point samples along P3 lat/lon path

Conclusions

- MRMS radar retrieved Dm, Nt, and IWC captured within approx. **50%, 100%, and 40%** of in situ aircraft observations, respectively.
- DGL enhancement regions of ZDR, KDP, and CDRp can represent two different particle populations: **1.) A variety of dry ice particles and 2.) A mixture of ice particles and supercooled liquid droplets.**
- Radar retrievals in DGL are more accurate using Z, ZDR, and KDP (RZ19) than just Z and KDP **(B20)** and non-polarimetric approaches such as **(H06)**.
- **Manuscript prepared for submission to *J. Appl. Meteor. Climatol.***

References:
Bukovcic, P., A. V. Ryzhkov and D. Zrnic, 2020: Polarimetric relations for snow estimation — radar verification. *J. appl. Meteor. Climatol.*, **59**, 1—52.
Hogan, R. J., M. P. Mittermaier, and A. J. Illingworth, 2006: The retrieval of ice water content from radar reflectivity factor and temperature and its use in evaluating a mesoscale model. *J. Appl. Climatol.*, **45**, 301—317
Ryzhkov A. V., and D. S. Zrnic, 2019: *Radar polarimetry for weather observations*. Springer Atmospheric Sciences, 486 pp.
Zhang, J. and Coauthors, 2016: Multi-Radar Multi-Sensor (MRMS) quantitative precipitation estimation: Initial operating capabilities. *Bull. Amer. Meteor. Soc.*, **97**, 621—638.

Acknowledgments

Funding was provided by NOAA/Office of Oceanic and Atmospheric Research under NOAA–University of Oklahoma Cooperative Agreement NA16OAR4320115, U.S. Department of Commerce and through the NSF Grant 1841246. The authors thank the NSSL MRMS team for access to the polarimetric MRMS data. We also thank Lynn McMurdie for her work as PI for the IMPACTS campaign and Mike Poellot, David Delene, and Gerry Heymsfield for their work with the aircraft measurements during the IMPACTS campaign.