Investigation of Microphysical Properties within Regions of Enhanced Dual-Frequency Ratio During the IMPACTS Field Campaign

Joseph A. Finlon[1], Lynn A. McMurdie[1], Randy J. Chase[2]

[1]Department of Atmospheric Sciences, University of Washington, [2]School of Computer Science and School of Meteorology, University of Oklahoma

1. Motivation

- Multi-frequency radar measurements can improve retrieval of snowfall properties from satellite observations
- Dual-Frequency Ratio (**DFR**): Reflectivity difference between two radars operating at different frequencies
- DFR is related to characteristic size D_m, used to retrieve particle size distribution (PSD) parameters, and influenced by microphysical processes

Research Questions

1. What can multi-frequency radar measurements tell us about the microphysics in snowstorms?
2. How are these observations related to banded precipitation structures?

2. Data & Methods

- W-band (CRS), Ku- and Ka-band (HIWRAP), X-band (EXRAD) reflectivity Z_e corrected for attenuation and matched to P-3 location
- PSDs: 2D-S (0.15–1.4 mm, 10 µm resolution), HVPS (1.4–30 mm, 150 µm resolution) every 5 s
- Scattering simulations from Leinonen & Szyrmer (2015; LS15) aided in deriving bulk microphysical properties (Fig. 1)

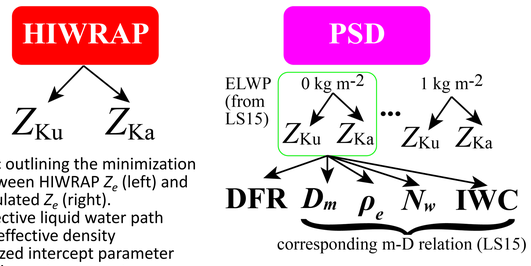

Fig. 1 Schematic outlining the minimization procedure between HIWRAP Z_e (left) and simulated Z_e (right).
ELWP = effective liquid water path
ρ_e = effective density
N_w = normalized intercept parameter
IWC = ice water content

- Variable DFR threshold considering the prominence and relative width of DFR peaks used to investigate whether DFR related to precipitation structures (Fig. 2)

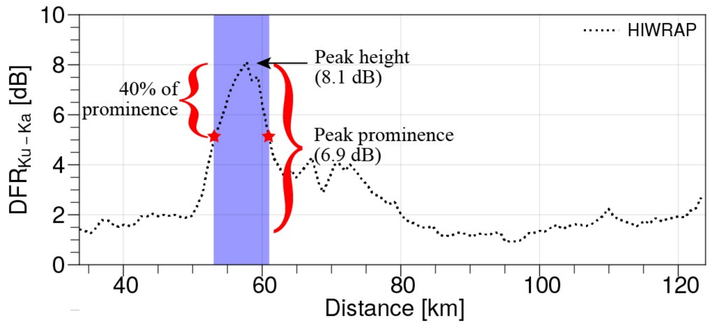

Fig. 2 Example of procedure used to detect prominently larger radar Ku- and Ka-band DFR (DFR$_{Ku-Ka}$) along the P-3 flight track. All DFR peaks with prominence ≥ 2 dB first identified, with times corresponding to DFR ≥ 40% of the prominence considered a region of enhanced DFR.

3. Regions of Enhanced DFR at Flight Level

Example: 05 February 2020

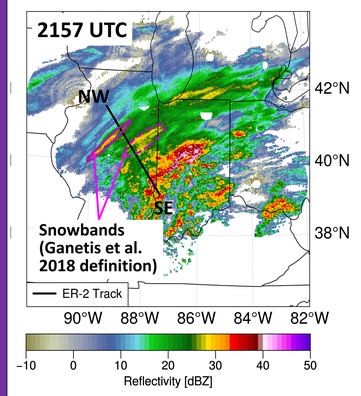

Fig. 3 2-km Z_e from NEXRAD mosaic.

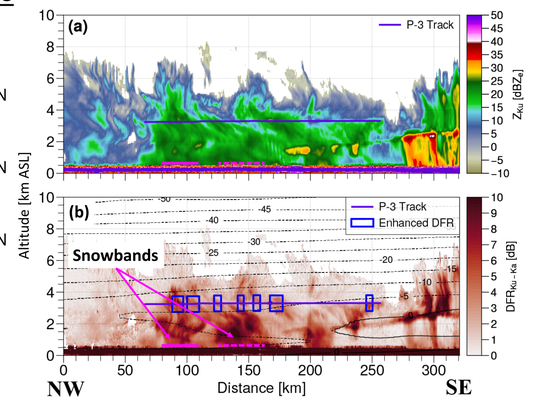

Fig. 4 HIWRAP cross-sections of (a) Z_{Ku} and (b) DFR$_{Ku-Ka}$. P-3 flight track (purple line) and regions of enhanced DFR (blue boxes).

- ER-2 and P-3 sampled banded precipitation structures (Figs. 3, 4)
- Larger D_m, smaller effective density ρ_e and intercept parameter N_w within regions of enhanced DFR consistent with an enhanced aggregation process (Figs. 5, 6)
- IWC has smaller response to changes in DFR due to having smaller N_w and less dense particles in regions of enhanced DFR

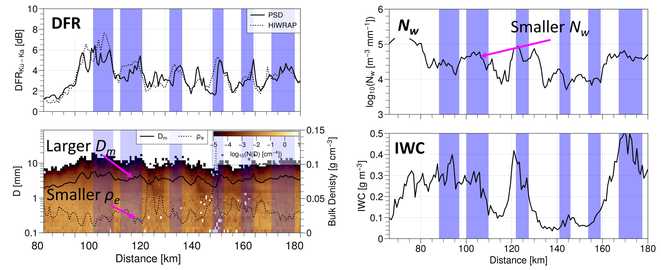

Fig. 5 Along-track DFR, D_m, ρ_e, N_w, IWC for the time period along the purple line in Fig. 4.

All Coordinated Flights

Enhanced DFR Regions

- Larger D_m (+58%)
- Smaller ρ_e (-37%)
- Smaller N_w (-74%)
- IWC values not notably different (-0.9%)

Note: 25 Jan & 01 Feb flights sampled different environments compared to the other flights.

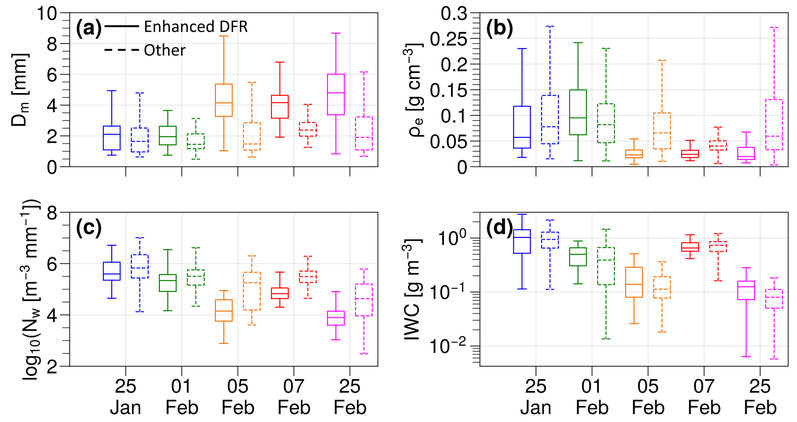

Fig. 6 Boxplots of (a) D_m, (b) ρ_e, (c) log$_{10}$(N_w), and (d) IWC for regions within (solid) and outside of (dashed) enhanced DFR for each coordinated flight.

4. Multi-Frequency Results

- Larger D_m farther from origin of DFR plane and larger ρ_e at lower DFR$_{Ku-Ka}$ consistent with scattering models and past studies
- "Hook" signature (Fig. 7a) not as pronounced as dendrite and unrimed aggregate models or some past studies (e.g., OLYMPEX)

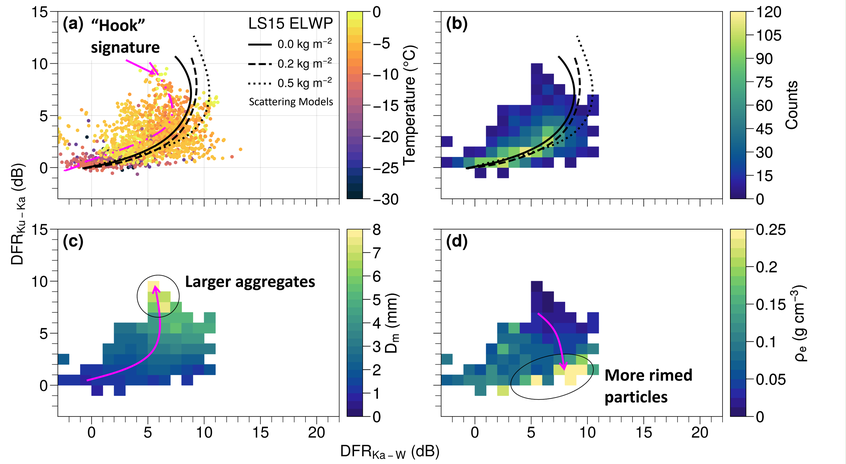

Fig. 7 (a) Scatterplot of temperature as a function of radar DFR$_{Ku-Ka}$ and DFR$_{Ka-W}$ with scattering curves from LS15. Panels (b)–(d): 2D histograms of (b) observation count, (c) mean D_m, (d) mean ρ_e.

5. Retrieved Microphysical Properties

- Neural network (NN) radar retrieval (Chase et al. 2021) used
- Negative correlation between D_m and N_w (aggregation; Fig. 8)
- D_m, N_w, IWC well correlated between NN and observations

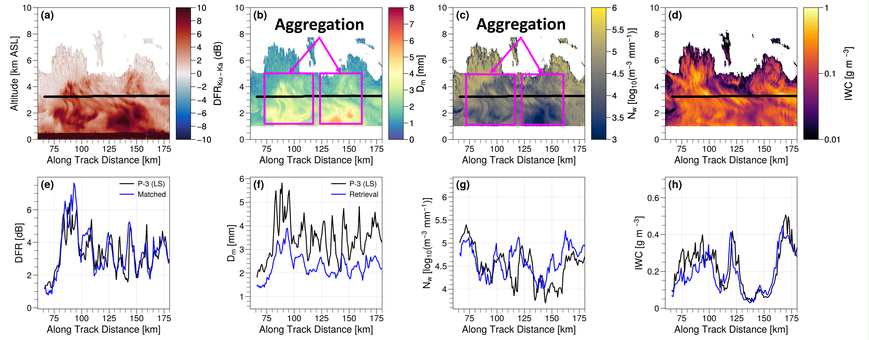

Fig. 8 Top row: Cross-sections of (a) DFR$_{Ku-Ka}$ and retrieved (b) D_m, (c) N_w, and (d) IWC for the same flight leg in Fig. 4. Bottom row: Comparison of the same properties as in (a-d) between the P-3 observations and the NN.

6. Conclusions

- Enhanced DFR associated with aggregation and co-located with regions identified as snowbands by Ganetis et al. (2018) criteria
- Neural network radar retrievals of microphysical properties compares well with observations
- Ultimately, NN based on DFR may be used to develop retrievals of microphysical properties from space-borne measurements

References

- Leinonen and Szyrmer, 2015: Radar signatures of snowflake riming: A modeling study. DOI:10.1002/2015EA000102.
- Chase et al., 2021: A Dual-Frequency Radar Retrieval of Two Parameters of the Snowfall Particle Size Distribution Using a Neural Network. DOI: 10.1175/JAMC-D-20-0177.1.
- Data publicly available at the NASA GHRC, DOI: 10.5067/IMPACTS/DATA101

- This work is funded by the NASA grant 80NSSC19K0338

Contact

Joseph Finlon
jfinlon@uw.edu
https://github.com/joefinlon