Hydrometeor Classification of Snow using a Fuzzy Logic Method

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Objective

The objectives are to identify hydrometeor classification equation sets that work for specific radar wavelengths and to verify those solutions using in situ measurements of snow particles during a regional snow event. Hydrometeor classification help in identifying heavy snow bands that can drastically change precipitation rates and affect surface conditions.

Introduction

The 20-21 November 2010 snow event near Grand Forks, North Dakota is studied using observations from two polarimetric radars and the University of North Dakota Citation Research Aircraft. The 20-21 November 2010 observations were obtained during a field project called Students Nowcasting & Observations with the DOW at UND: Education through Research (SNOwD UNDER). Bulk snowflake types were identified using a hydrometeor classification algorithm (HCA) that uses polarimetric radar variables as input. The HCA results are compared with in situ ("truth") images of particles collected using a Two Dimensional Cloud Imaging Probe (2DC). Attention is focused on times when the aircraft is passing between two HCA-identified crystal type regions.

Methodology

Processing Radar Data

- *RSL library - converts radar files between UF format & sweep format*
- *SOLOii - removes ground clutter and rotate radar orientation*
- *Reorder - interpolate spherical coordinate data to Cartesian*
- *HCA – classifies the dominant hydrometeor type at each location*

Processing Aircraft Data

- *Used CPLOT software to*
- *Visualize precip particles*
- *Plot sizes versus concentration*
- *Plot aircraft tracks*

Background

Meteorological Definitions of Snow and Ice

- *Dendrites (a type of ice crystal) are one single snowflake*
- *Aggregates are multiple dendrites and other crystals clumped together*

Polarimetric Radar

- *Linear polarimetric radars send out pulses in both horizontal and vertical orientations*
- *Can be used to determine average precipitation particle shape*
- *Two polarimetric wavelengths used (3 cm-DOW; 5 cm-UND)*

Hydrometeor Classification Algorithm (Marzano et al.) [1]

- *Using polarimetric variables (zhh, zdr, kdp) and air T, gives probability of hydrometeor species (Relevant : ice crystals, dry snow, & graupel)*

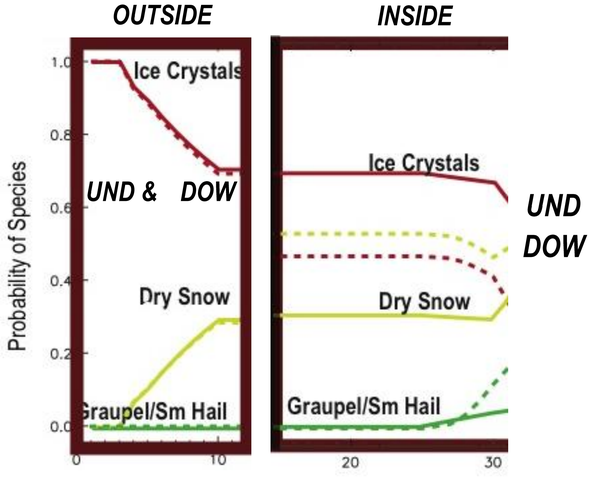

Figure 1: Probabilities of species outside the bands, using the Marzano et al. hydrometeor classification algorithm, as a function of dBz for both the UND (solid) and DOW (dotted). Mean values of ZDR (2.3 DOW; 0.72 UND) and KDP (0.06 DOW; -0.01 UND) outside the bands, along with an approximate air temperature of –10°C from the Bismarck sounding were used in computing these curves..

Figure 2: As in Fig. 1 except for inside the bands for both the UND (solid) and DOW (dotted). Mean values of ZDR (0.42 DOW; 0.88 UND) and KDP (0.04 DOW; 0.05 UND) inside the bands, along with an approximate air temperature of –10°C from the Bismarck sounding, were used in computing these curves.

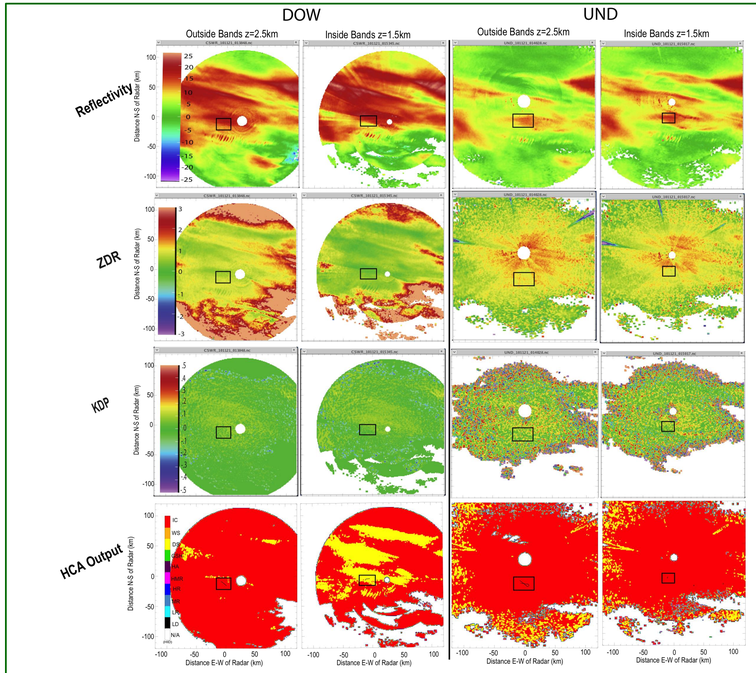

Figure 3: CAPPI's of Reflectivity, ZDR, KDP, and HCA output with aircraft track overlaid at the times and altitudes indicated. The only HCA-identified species here are ice crystals (red) and dry snow (yellow).

Comparison of UND and DOW Radars with 5cm Algorithm

- *Reflectivity for both UND and DOW…*
  - *Minima similar*
  - *Larger inside the banded regions (slightly larger maxima for DOW)*

ZDR values are, for DOW:
- *0 within the band - aggregates*
- *1 outside the bands - ice crystals*
- *Less noisy than UND's radar*

KDP values are, for DOW
- *.1 inside bands*
- *0 outside of bands*
- *Less noisy than UND's radar*

(Note: used to discriminate between rain and ice hydrometers [1] so perhaps not useful here)

Constant altitude cross sections of HCA output
- *Show the most likely hydrometeor type at each location*
- *Reflectivity and ZDR bands (1st two rows of plots) support…*
  - *Dry snow aggregates for DOW*
  - *Ice crystals for UND (but likely due to noisy ZDR)*

Polarimetric Variables and Plots

Table showing hydrometeors and their corresponding polarimetric radar values [2]

Polarimetric Variable	*Definition*	*Values for snow and ice*
Zh (horizontal reflectivity)	*Related to the fraction of backscattered power from hydrometeors*	*-20 to 40 dBz*
ZDR (differential reflectivity)	*Ratio between the horizontal and vertical reflectivity. Major player in the HCA.* 	*Dry aggregated snow: 0.1 to 0.3 dB Horizontally-oriented ice: 4 to 5dB Ice: -2 to 0 dB*
KDP (specific differential phase)	*The difference in differential phase between two point at different ranges*	*For snow and ice: -2 to +7 deg/km (usually zero)*

Aircraft Results

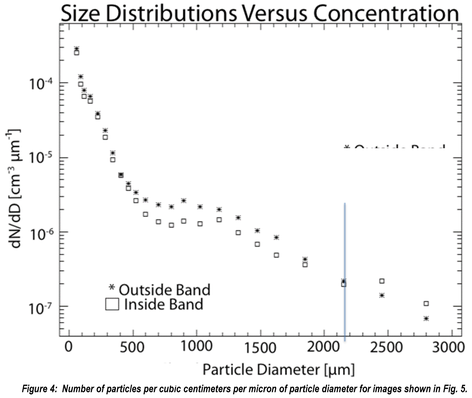

Figure 4: Number of particles per cubic centimeters per micron of particle diameter for images shown in Fig. 5.

2DC Images of Ice Crystals and Dry Snow

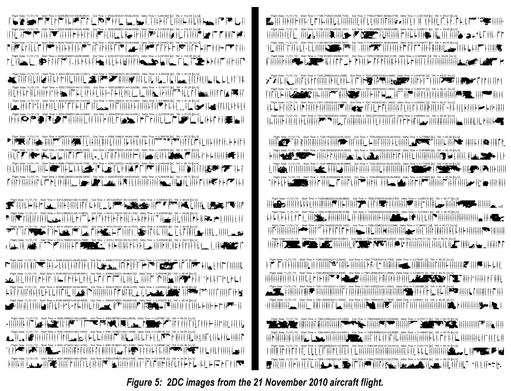

Figure 5: 2DC images from the 21 November 2010 aircraft flight.

Conclusion

- *5-cm HCA also appears to work at 3 cm*
- *Snowbands are associated ZDR near zero & larger reflectivity giving HCA-detected "dry snow"*

Future Work

Check consistency of these results with 3 other SNOwD UNDER cases and on different aircraft legs of this same case

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References

[1] Marzano F.S.Univ of Rome "La Sapienza,Rome, D.Scaranari, and G.Vulpiani,2007:Supervised Fuzzy-Logic Classification of Hydrometeors Using C-Band Weather Radars,IEEE Trans. on GeoScience and Remote Sensing,45, 3784 - 3799

[2] National Oceanic & Atmospheric Administration,cited 2012:Dual-Polarization Radar Training. [http://www.wdtb.noaa.gov/courses/dualpol/]