Polarimetric Radar Observations of Bow Echoes with Descending versus Non-Descending Rear Inflow Jets

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Background, Motivation, and Study Overview

- Well understood that a bow echoes (Figure 1) descended rear inflow jet (RIJ) (Figure 1) can cause damaging straight-line winds.
- Difficult to discern descending versus non-descending RIJs operationally due to ssues with radar sampling in the near-surface layer (Figure 2).
- Dual polarization upgrades of the National Weather Service WSR-88D network vastly increases data available for storm structure and microphysical processes analysis.

One avenue for rear inflow descent is via downdrafts driven by negative buoyancy. Negative buoyancy is often created via cooling effects from melting and evaporation, both of which are tied to microphysical processes within the bow echo.

This study is using polarimetric radar to assess the microphysical characteristics of bow echoes to identify distinct polarimetric signatures that can be used to differentiate descending and non-descending RIJs operationally. We hypothesize that signatures related to the presence of a well-defined melting layer and the presence of low concentrations of small droplets (favoring evaporation) may be most useful in this application.

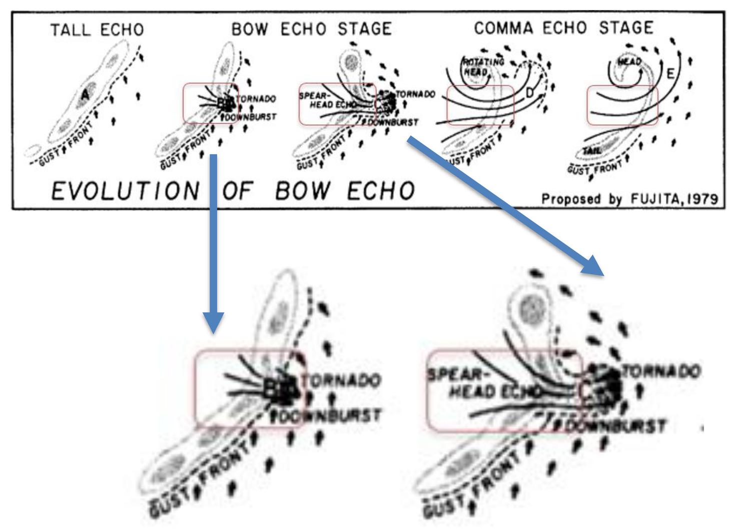


__Figure 1.__ Bow echo life cycle first proposed by Fujita 1979. Highlighted area is expected location of a RIJ (Fujita, 1979).

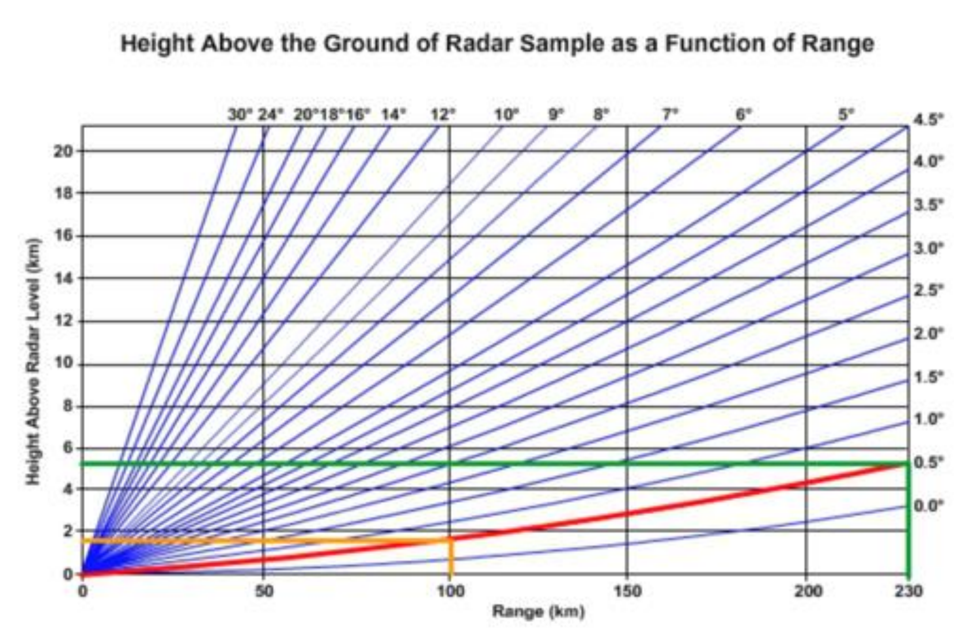


__Figure 2.__ Limited distance of near-surface NEXRAD WSR-88D sweeps places a spatial constraint on the pool of applicable candidates (NOAA MetEd, 2017).

Bow Echo Candidate Identification and Analysis Methods

- **Initial selection criteria**
  - Identified bow echo cases from archived reflectivity mosaics for 2013-2015.
  - Spatial constraints to allow for near-surface sweeps collecting RIJ descent (< 100 km from probable RIJ location).
  - Focused on cases with weak synoptic forcing, where convection processes dominate.
- **Final selection criteria**
  - Storm Prediction Center severe weather reports analyzed to help confirm likely cases of RIJ descent.
    - Focused on reports of widespread damaging winds along storm track.
  - Velocity slice of approximate RIJ location viewed to confirm presence of RIJ and status of descent.
- PyART[1] open source radar software used to plot correlation coefficient (CC) and differential reflectivity (ZDR) products to identify regions of melting and possible evaporating hydrometeors and reflectivity (Refl) to show hydrometeor concentration.

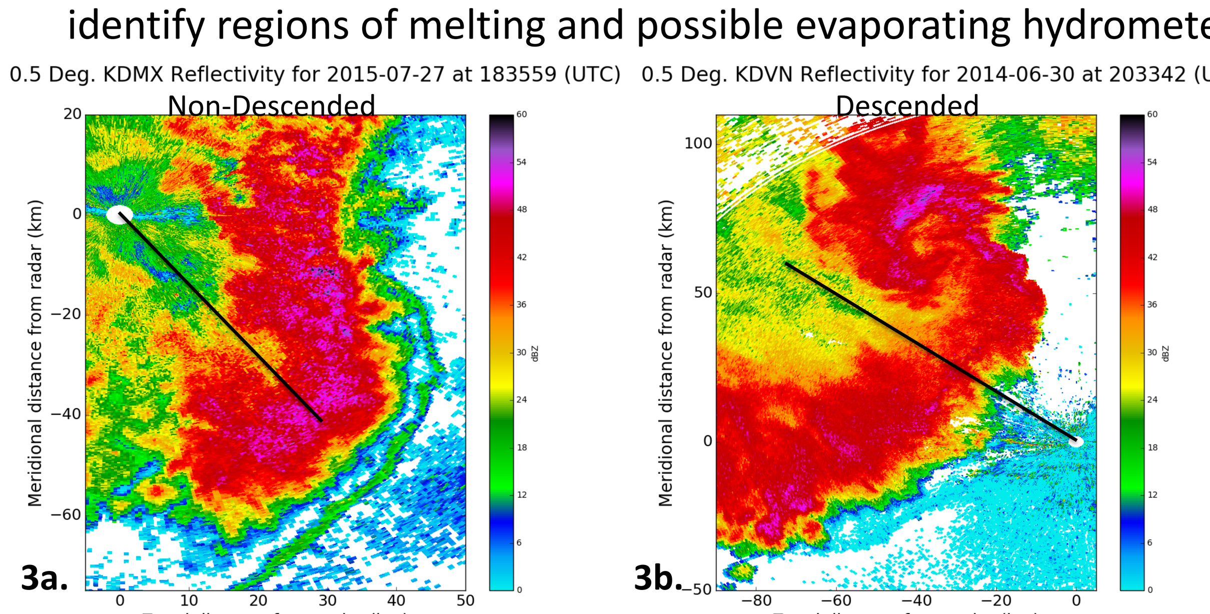


__Figure 3.__ 0.5° reflectivity of a (3a) non-descending and (3b) descending bow echo. 3a shows the non-descending bow echo travelling southeastward away from KDMX over south-central Iowa on 27 July 2015 at 18:35:59 UTC. 3b shows the descending bow echo travelling eastward over KDVN in east-central Iowa at 20:33:42 UTC on 30 June 2014. Slices are represented by black lines.

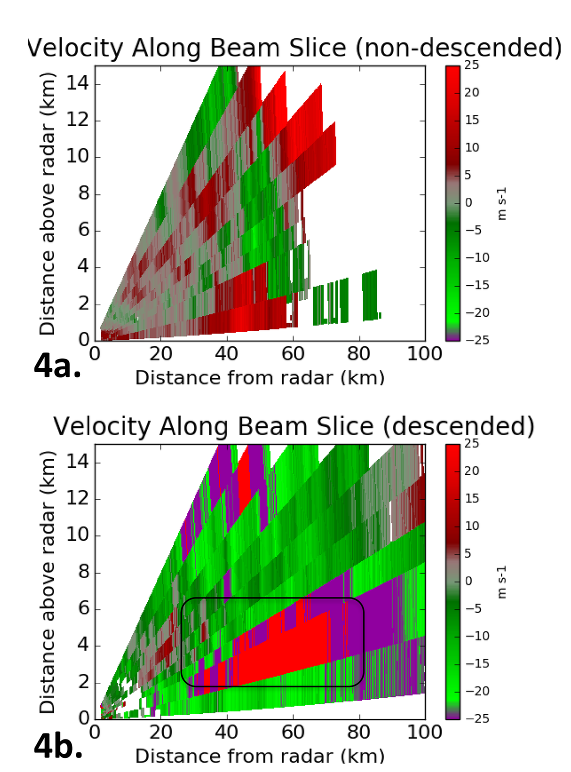


__Figure 4.__ Along beam slice of inbound and outbound velocity used to determine and confirm status of RIJ descent. 4a is the non-descended RIJ from 132° east of north from KDMX. 4b is the descended RIJ from 305° east of north from KDVN.

Initial Case Study Results

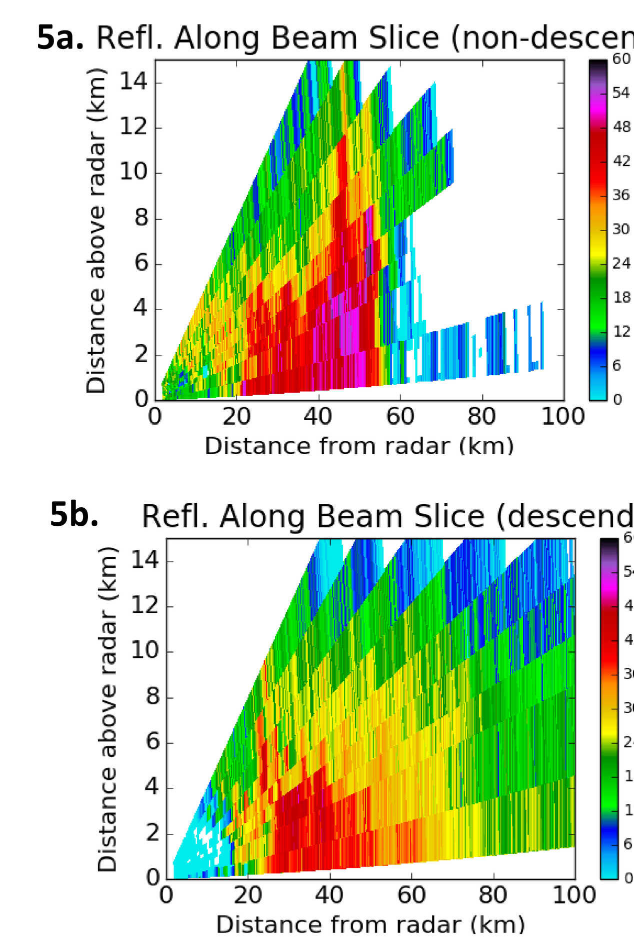
Times of Observation

NON-DESCENDED: 18:35 UTC

DESCENDED: 20:33 UTC

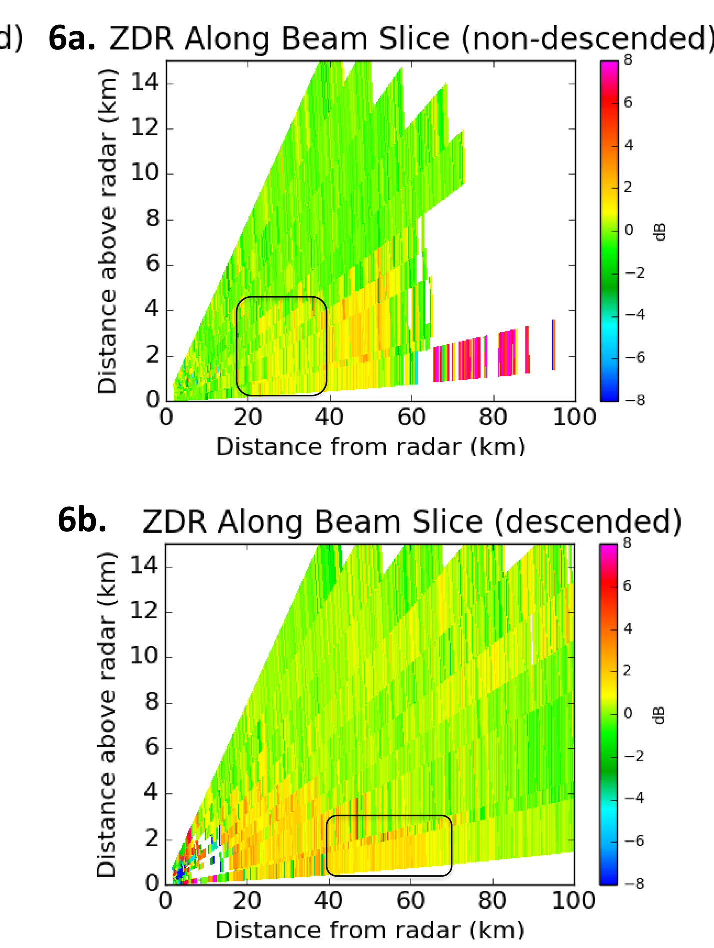
Reflectivity (Refl)

__Figure 5.__ Along beam reflectivity used for estimating hydrometeor concentration. 5a is the non-descended RIJ from 132° east of north from KDMX. 5b is the descended RIJ from 305° east of north from KDVN.



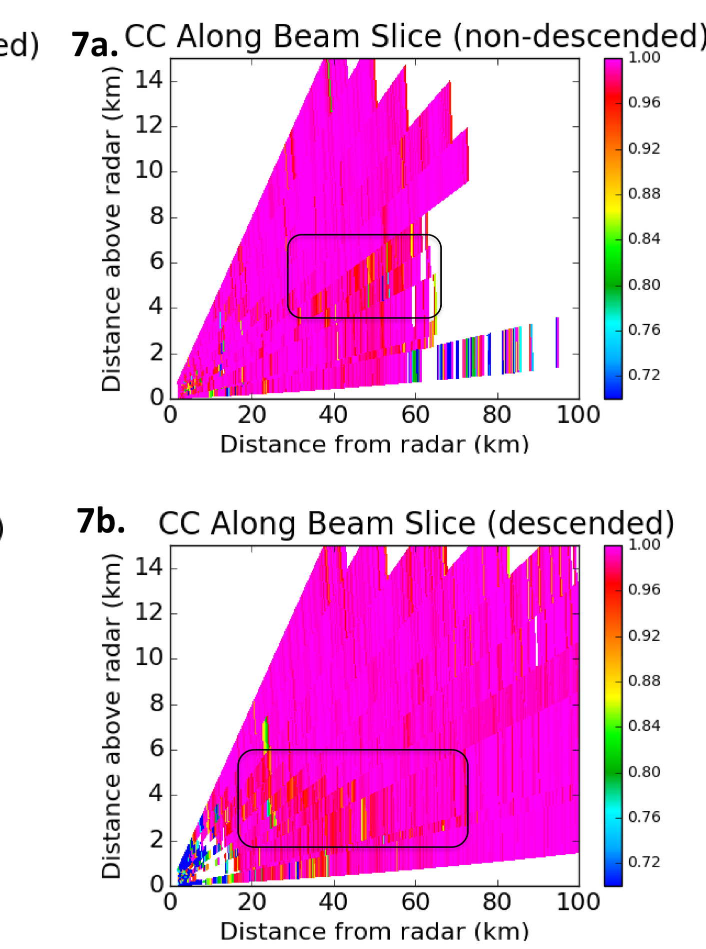
Differential Reflectivity (ZDR)

__Figure 6.__ Along beam differential reflectivity used for estimating drop size and shape of hydrometeors. 6a is the non-descended RIJ from 132° east of north from KDMX. 6b is the descended RIJ from 305° east of north from KDVN.



Correlation Coefficient (CC)

__Figure 7.__ Along beam correlation coefficient used to estimate position of the melting layer. 7a the non-descended RIJ from 132° east of north from KDMX. 7b the descended RIJ from 305° east of north from KDVN.



Discussion and Future Work

Summary of Initial Case Study Findings

- Reflectivity (Refl):
  - Non-descended – Updraft associated with the lowest descent of RIJ (about 2km above ground level).
  - Descended – Largest hydrometeor concentration ahead of RIJ in the updraft region.
- Differential Reflectivity (ZDR):
  - Non-descended – Possible region of evaporating rain (large dBZ returns & positive, low dB values).
    - Possible trigger for forcing RIJ descent in future storm track locations (although not seen from velocity).
  - Descended – Low-level band of large stratiform drops and indication of rain core within updraft.
- Correlation Coefficient (CC):
  - Non-descended – **Melting layer located between 4.0 – 6.5 km** (positive slope) through all observation times.
  - Descended – **Melting layer located between 3.5 – 4.5 km** (negative slope) through all observation times.

Future Work and End Goals

- Expand pool of case study candidates to further identify more microphysical features suggesting descent status of RIJs
  - Include specific differential phase in the observational analysis
  - Winter 2017
- WRF-ARW modeling of case study candidates to apply identified microphysical interactions of RIJs to bow echo cold pools
  - Spring 2017 – Fall 2017
- Compile a set of microphysical properties and distribute among operational forecasters to aid in identification of future RIJ descent (especially applicable where conditions are lacking surface wind observations)

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Data Sources:
College of DuPage & NCEI, SPC, NCAR

References:

[1]Helmus, J., & Collis, S. (2016). The Python ARM Radar Toolkit (Py-ART), a Library for Working with Weather Radar Data in the Python Programming Language. *Journal of Open Research Software*, *4*(1).