CATALOGING RAPID SCAN OBSERVATIONS OF Z_{DR} COLUMNS IN SUPERCELLS

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1. Introduction

The height and intensity of a differential reflectivity (Z_{DR}) Column have been hypothesized to have a strong correlation to a supercell's updraft strength, which is pertinent for tornadogenesis (Picca et al. 2015). However, during severe weather, the volume coverage pattern used by the National Weather Service WSR-88D only scans the mid-levels (2-6 km AGL) every 5 to 6 minutes, thus preventing the study of Z_{DR} column behavior immediately preceding tornadogenesis. Accordingly, several data sets collected in supercells during previous projects were examined in an effort to gain better understanding of Z_{DR} columns and their relationship to tornadogenesis and tornadogenesis failure. Along with the main hypothesis are several sub-hypotheses that are investigated during phase I of this project. These sub-hypotheses are:

1. Z_{DR} Column height increases, then decreases with altitude in the five minutes prior to tornadogenesis or tornadogenesis failure (Picca et al. 2015).
2. Z_{DR} Column volume increases, owing to intensification of the supercell's updraft as well as suspended, supercooled liquid water droplets
3. Z_{DR} column intensity (defined as the difference in Z_{DR} between the interior of the column and its immediate surroundings) increases prior to tornadogenesis

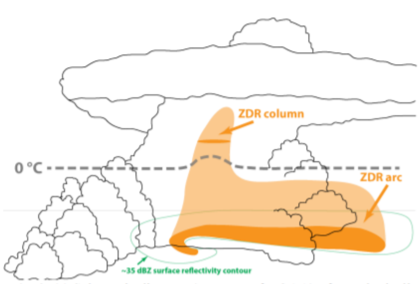

Fig. 1. A right-moving supercell thunderstorm schematic displaying the location of enhanced Z_{DR} (orange shading) prior to tornadogenesis or tornadogenesis failure. The gray dashed line annotates the environmental melting layer where Z_{DR} columns initiate and increase in height. Lastly, the dark orange region located with in the column is a cross-section of the column's maximum areal coverage.

This document provides an explanation of the methodology followed in order to examine the collected data sets along with the presentation of a detailed Z_{DR} column case catalog. Additionally, conclusions will be discussed with respect to the sub-hypotheses outlined above.

2. Methodology

Each data set was interrogated utilizing Solo II (Oye et al. 1995; https://eol.ucar.edu/software/solo-ii). The software allowed for manual identification of Z_{DR} columns in the five minutes prior to tornadogenesis or tornadogenesis failure. Moreover, other characteristics were examined; namely the column's height, longevity, intensity, and any splits and/or mergers that may have occurred.

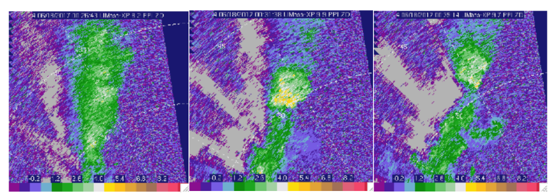

Fig. 2. Example of a Z_{DR} column life cycle, observed by the UMass X-Pol (Bluestein et al. 2007) in a supercell near Baring, Missouri on 18 June 2017. Panels show Z_{DR} (in dB) observed at an elevation angle of; (a) 8.7 degrees at 0027 UTC, when the column was in its developing stage, (b) 9.9 degrees at 0032 UTC, when the column reached maturity, and (c) 9.7 degrees at 0035 UTC, as the column dissipated. All of these observations were made above the environmental 0° C freezing level. Range rings are in increments of 15 km, and azimuth spokes appear every 30 degrees.

The data obtained from examining each case were then compiled into a large Z_{DR} column case catalog containing detailed notes on each event. In order to accurately measure the column's height, the environmental 0°C freezing level must be identified. Precise measurement from the Z_{DR} column's base (commonly found at the environmental freezing height) to its maximum height allows for further understanding on how increasing column height correlates to a supercell's updraft. Proximity soundings were used whenever possible; when they were not available, archived model soundings (such as those from the Rapid Refresh model) were used instead.

3. Z_{DR} Column Case Catalog

Data displayed in the catalog were harvested from archives contained in the Earth, Atmospheric, and Planetary Science department at Purdue University, as well as by reaching out to other researchers at other universities known to operate rapidly scanning polarimetric radars. Currently, ten cases have been identified in which rapid-scan volumetric observations were made of supercells containing Z_{DR} columns. The radars used include UMass X-Pol (Bluestein et al. 2007), PX-1000 (Kurdzo et al. 2015), and RaX-Pol (Pazmany et al. 2013). After interrogation of all the cases, aggregate statistics surrounding Z_{DR} columns were derived:

- The height of a Z_{DR} column ranged from 3 to 6 km above the environmental freezing level
- The longevity of a Z_{DR} column ranged from one to 10 minutes, with a mean longevity of 5.5 minutes
- The maximum intensity of the Z_{DR} column ranged from 5 to 7 dB, with a mean of 6 dB.

Table 1. Z_{DR} column case catalog containing data on the characteristics of each column as described in section 2 of this document.

Case #	DATE (MM/DD/YYYY)	Start Time (UTC)	End Time (UTC)	Radar	Location	Reference	Storm Type	Height (km)	Intensity (dB)	Duration (min)
1	05/19/2013	2140	2150	PX-1000	Norman, OK	Cheong	Supercell	5.879	5.5	10
2	04/29/2016	2114	2216	PX-1000	Norman, OK	Cheong	Embedded Supercell in QLCS	5.370	5.0	1
3	06/18/2017	0027	0034	UMass-XPol	Baring, MO	Tanamachi	Supercell	5.526	6.0	7
4	06/22/2017	0249	0255	UMass-XPol	Moville, IA	Tanamachi	Supercell	3.027	6.5	6
5	05/24/2016	0120	0125	UMass-XPol	Dodge City, KS	Tanamachi	Supercell	3.000	5.0	5
6	05/06/2007	0136	0140	UMass-XPol	Greensburg, KS	Tanamachi	Supercell	3.728	6.0	4
7	05/19/2013	2145	2150	RaX-Pol	Norman, OK	Bluestein	Supercell	6.007	6.0	5
8	05/24/2016	0124	0125	UMass-XPol	Woodward, OK	Tanamachi	Supercell	5.630	5.0	1
9	05/31/2013	2300	2309	RaX-Pol	El Reno, OK	Bluestein	Supercell	6.474	6.0	9
10	05/20/2013	1951	1955	Rax-Pol	Moore, OK	Bluestein	Supercell	6.147	6.0	4

4. Conclusions

Through interrogation of each of the cases listed in the catalog above, conclusions were made pertaining to the sub-hypotheses outlined in section one:

1. Z_{DR} columns do indeed increase with height, and then decrease prior to tornadogenesis. All of the cases through which contained tornadoes exhibited this increase followed by a decrease in height as the tornado developed from the supercell. As an example, we highlight Case 7 (Table 1). A Z_{DR} column developed prior to tornadogenesis, increasing to a maximum height of 6 km above the environmental freezing level. The column’s intensity was approximately 6 dB, which is an average intensity for cases in this catalog according to the aggregate statistics derived through research in this phase. All of the Z_{DR} column’s characteristics were indicative of a strong updraft that would be expected to be associated with a violent tornado. As for cases that were non-tornadic, Z_{DR} columns were identified, however, their increase in height was negligible compared to those cases containing tornadic supercells. The columns entered the dissipation stage immediately as tornadogenesis failed.
2. Research continues on objective methods to assess a Z_{DR} column's volume; therefore, we cannot draw any definitive conclusions about the relationship between the volume and tornadogenesis at this time. However, it has been observed a past case (Tanamachi and Heinselman 2016) that multiple ZDR columns merged into a single column prior to tornadogenesis, suggesting that an increase in Z_{DR} column volume may indeed precede a tornado. In that case, the update frequency of the radar used (KOUN) was not fast enough to qualify as "rapid scanning" by our definition (<= 2 min updates). The present batch of Z_{DR} columns are currently being examined further to assess their volumes and how they correspond to a supercell’s updraft.
3. A Z_{DR} column’s intensity has been found to increase prior to tornadogenesis. From examining each case, intensities were found to be between 5 and 7 dB. The intensity of each column began to increase during the development stage of a Z_{DR} column and climax during a column’s mature stage.

Several cases in the catalog were found to be at 6 dB of intensity in the column while others peaked at approximately 5 dB. The peak in intensity correlates with tornadogenesis as it occurs.

5. Future Work

This Z_{DR} column catalog is still a work in progress, drawing off data sets available in the public domain and those known to the authors. A key objective in this phase is to robustly identify any relationships between Z_{DR} column characteristics and low-level rotation. Furthermore, any insights gained through this catalog will inform scanning strategies for future supercell observations to be collected using a rapid-scan, dual-polarized mobile radar to be fielded in spring 2019.

Acknowledgements

This work was supported by NSF Award #AGS-1741003. A special thank you also goes out to the Purdue College of Science IT department for their and technical support with setting up Solo II as well as troubleshooting errors. Lastly, thank you to Milind Sharma, a Ph.D. student in the Earth, Atmospheric, and Planetary Science department, for his guidance and support.

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