EVALUATING SEVERE CONVECTIVE WIND ENVIRONMENTS AND RADAR SIGNATURES

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1. Introduction

The National Weather Service (NWS) has defined a severe thunderstorm as one with large hail (≥1" in diameter) and strong winds (≥50 kt wind gust). Due to recent improvements to the WSR-88D network, large hail has become easier to identify in radar data, while recognizing damaging winds remains a challenge. A downburst is a strong downdraft that causes an outflow of damaging winds at or near the surface. When downburst winds strike the surface, they spread out horizontally very quickly and can pose a threat to aviation and property. Forecasting for downburst events proves challenging even for veteran forecasters. The dual polarization upgrade to the WSR-88D network provides forecasters with additional information to better evaluate storms with downburst potential. This research seeks to isolate any trends or patterns in environmental parameters and radar signatures leading up to downburst events, with the specific goal of assisting NWS forecasters in improving precision, confidence, and lead time when making downburst warning decisions.

2. Methods

This study evaluated 19 downburst events throughout northern Ohio and northwest Pennsylvania between 2012 and 2017. BUFKIT was used to analyze numerical weather model environmental parameters believed to indicate a prime environment for downbursts. The environmental parameters used in this study—Surface to LCL Lapse Rate, Delta Theta-E, and Downdraft CAPE—were determined by previous studies including Fujita & Wakimoto (1981) and Kingsmill & Wakimoto (1991) to be important factors in the formation of downbursts. Three categories of downburst risk potential—Strong, Moderate, and Marginal (FIG. 1)—were created using severity thresholds for each of the three aforementioned environmental parameters. GR2Analyist was utilized in order to interrogate radar data, specifically changes to Base Reflectivity (Z), Differential Reflectivity (ZDR), and Specific Differential Phase (KDP) in the time leading up to downburst initiation. For each of the 19 cases the moment of downburst initiation was determined using archived radar data. Then, utilizing GR2Analyst, radar data for four scans leading up to the previously determined time of initiation were collected. For each radar scan, the highest value of each radar parameter—Z, ZDR, and KDP—and the height at which the maximum occurred in the storm volume were recorded. The maximum radar parameter values and the associated height of occurrence in the storm volume were then graphed with respect to time. Because downbursts occur on very short timescales, it proved challenging to develop a longer data record than four radar scans—about 16 minutes—before downburst initiation. Linear regressions were then run on each radar parameter with respect to height of occurrence to determine how correlated each radar parameter was with height of occurrence. Information on how radar parameters behave with height is crucial for forecasters that monitor severe weather and make warning decisions.

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2.1 *Downburst Risk Potential Environmental Thresholds*

Environmental Parameter	Strong	Moderate	Marginal
Lapse Rate (sfc to LCL)	≥ 8.0 °C/km	8.0 °C/km > X ≥ 7.0 ° C/km	< 7.0 °C/km
Delta Theta-E	≤ -30 K	-30 K < X ≤ -20 K	> -20 K
Downdraft CAPE	≥ 1000 J/kg	900 J/kg > X ≥ 700 J/kg	700 J/kg > X ≥ 500 J/kg

FIG. 1: Each environmental parameter used in this study is listed and includes category name as well as numerical thresholds for each category of severity.

3. Findings

When each radar parameter was graphed with respect to height of occurrence and also plotted in relation to the freezing level (0°C Level), each parameter told a different story. Reflectivity behaved as expected; it had a strong correlation (*r = 0.88*) with height of occurrence in each of the three downburst risk potential categories—Strong, Moderate, and Marginal. Reflectivity consistently increased very rapidly in both intensity and height a few minutes—about one scan—before downburst initiation. This behavior confirmed a previous forecasting guideline for downbursts—i.e. the importance of awareness of abnormal reflectivity "spikes" in radar data. ZDR behavior departed from the expected behavior that it would correlate strongly with height of occurrence. In actuality, ZDR and height of occurrence were moderately correlated ($r = 0.67$) in Strong environments and weakly correlated ($r = 0.40$) in Moderate and Marginal environments. The rapid increase in ZDR and height of occurrence was only a useful indicator of downburst potential in Strong environments. Likewise, ZDR and reflectivity were moderately correlated ($r = 0.66$) in Strong environments, which proved to be a decent indicator for downburst behavior. KDP behavior proved to be a rather useless metric for downburst behavior when analyzed on its own. However, KDP strongly correlated ($r = 0.77$) with ZDR in Strong environments. KDP demonstrated usefulness as a confirmation of potentially severe ZDR behavior leading up to a downburst event.

4. Conclusions

A set of guidelines were developed to increase the situational awareness and confidence of NWS forecasters when making downburst warning decisions. These guidelines were developed specifically for the operational forecasters of the NWS Cleveland, OH forecast office. For each radar parameter—Z, ZDR, and KDP—guidelines were created to describe patterns of behavior indicative of impending downbursts. The height of each radar parameter above the freezing level was also taken into account in the guidelines as it was found to be an important indicator for downburst behavior and simpler to use operationally. General "Rules of Thumb" for forecasters advise to remain situationally aware in downburst potential environments and heavily focus on monitoring the reflectivity core. In general, reflectivity and ZDR values will peak around the same time leading up to downburst initiation. Operational forecasters must also monitor ZDR and KDP spikes occurring in the same area of a storm volume because this is a strong indicator of water loading.

Overall, this study developed guidelines to improve downburst forecasting and situational awareness of operational forecasters, confirmed a previous guideline detailing the importance of monitoring reflectivity behavior in downburst potential environments, and demonstrated the usefulness of consulting dual-pol products when making downburst warning decisions.

5. References

Fujita, T.T., and R. M. Wakimoto, 1981: Five scales of airflow associated with a series of downbursts on 16 July 1980. *Mon. Wea. Rev*., 109, 1438-1456

Kingsmill, D. E., and R. M. Wakimoto, 1991: Kinematic, dynamic, and thermodynamic analysis of a weakly sheared severe thunderstorm over northern Alabama. *Mon. Wea. Rev*., 119, 262-329

Knupp, K. R., 1989: Numerical simulation of a low-level downdraft initiation within precipitation cumulonimbi: Some preliminary results. *Mon. Wea. Rev*., 117, 1517-1529.

Kramar, M., 2016: It's Going Down! Part I: The Downburst Environment [Web log post].

Roberts, R. D., and J. W. Wilson, 1988: A proposed microburst nowcasting procedure using single-doppler radar.