# Evaluating Severe Convective Wind Environments and Radar Signatures

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**Abstract**

*The National Weather Service (NWS) has defined a severe thunderstorm as one with large hail (≥1" in diameter) and strong winds (≥50 knot wind gust). Due to recent improvements to the Weather Surveillance Radar 1988 Doppler (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 most recent upgrade to the WSR-88D network provides forecasters with additional information to better evaluate storms with downburst potential. This study 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.*

*This study evaluated 19 downburst events throughout northern Ohio and northwest Pennsylvania between 2012 and 2017. BUFKIT, a forecast profile visualization and analysis tool kit program, was used to analyze numerical weather model environmental parameters believed to indicate a prime environment for downbursts. Additionally, GR2Analyist was used 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. A set of guidelines were developed to increase the situational awareness and confidence of NWS forecasters when making downburst warning decisions. Situational awareness is crucial because it is the job of the NWS to protect the public by monitoring severe weather and disseminating timely warnings to the public.*

## Background and Methodology

A downburst is a strong downdraft that causes an outflow of damaging winds at or near the surface. This study evaluated 19 downburst events throughout northern Ohio and northwest Pennsylvania between 2012 and 2017. BUFKIT, a forecast profile visualization and analysis tool kit program, was used to analyze numerical weather model environmental parameters believed to indicate a prime environment for downbursts. The environmental parameters used in this study were determined by previous studies including Fujita & Wakimoto (1981) and Kingsmill & Wakimoto (1991) to be important factors in the formation of downbursts.

GR2Analyst, a computer application that is used to analyze current and archived radar data, was utilized in this study 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. Base Reflectivity is what is typically seen when using a weather radar. Generally, low to high reflectivity is denoted by a color bar that runs from green to red respectively. Higher values of reflectivity generally indicate areas of heavier precipitation. Differential Reflectivity is used to visualize the shape of hydrometeors—i.e. water droplets, hail, and ice—in a storm. Specific Differential Phase used to visualize the shape and concentration of hydrometeors in a storm.

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—i.e. highly correlated, moderately correlated, or no correlation. Information on how radar parameters behave with height is crucial for

forecasters that monitor severe weather and make warning decisions.

| 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: Downburst risk potential thresholds. Each environmental parameter used in this study is listed and includes category name as well as numerical thresholds for each category of severity.

## Findings

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. 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 with height of occurrence in each of the three downburst risk potential categories—Strong, Moderate (FIG. 2), 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 in Strong environments and weakly correlated 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 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 with ZDR in Strong environments. KDP demonstrated usefulness as a confirmation of potentially severe ZDR behavior leading up to a downburst event.
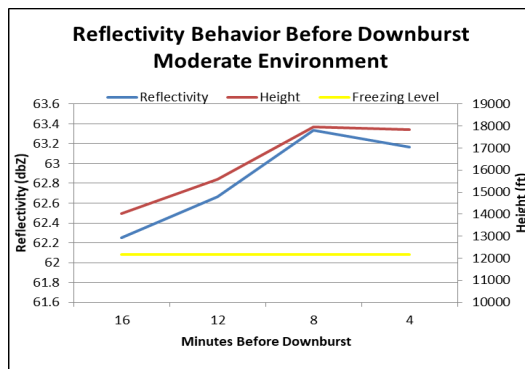


FIG. 2: An example of a radar parameter graphed with respected to height for a moderate risk environment. The height of the freezing level is also represented.

## 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 based on the specific warning criteria of the office. Each of the downburst cases analyzed occurred within the Cleveland office's County Warning Area (CWA), the area of responsibility for that 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—the area in a storm with the highest reflectivity returns. 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—an area saturated with a large amount of water.

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 updated radar products when making downburst warning decisions.

# References

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