5.3 DEVELOPMENT OF WARNING CRITERIA FOR SEVERE PULSE THUNDERSTORMS IN THE NORTHEASTERN UNITED STATES USING THE WSR-88D

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1. INTRODUCTION

In recent years, identification and warning skill for significant, well organized severe convective systems have improved steadily in the northeast United States. Derechos, tornadoes, and supercell thunderstorms are relatively easily identified and often warned for with lead times in excess of 30 minutes as a result of improved understanding of these systems and the environments they evolve in. (LaPenta et al. 2000; Cacciola et al. 2000b; Cannon et al. 1998).

From Storm Data, the majority of un-warned severe thunderstorm events met the description by Lemon (1977) of "Pulse" severe thunderstorms. These were generally characterized by weak flow and shear environments, slow movement, and the identification of an elevated core of high reflectivity. The storms themselves were characterized as short lived, on the order of 30 minutes to 2 hours, appeared random and not triggered by any organized dynamic feature. They typically produced severe weather (hail with diameter greater than 1.88 cm or wind gusts in excess of 25 m/s) for only a short period, often less than 15 minutes. Lemon's technique identified the elevated cores with manual real time interrogation by the radars then in use, and warnings were issued when storms reached criteria. Even so, storms could not always be identified in time to issue a useful warning when numerous storms were on the scope. The automated scan strategy of the WSR-88D has made Lemon's technique for identifying pulse storms unworkable.

2. DATA AND CRITERIA

Data from 1995, 1996, 1997 and 1998 were used for this study. The area of study was all of New England, New York, New Jersey, and most of Pennsylvania.

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Each event was then compared to the National Radar Archive from the National Climatic Data Center (NCDC). Initially the following types of events were eliminated; those organized along a line, front, bow echoes, those that were tornadic, those that contained a mesocyclone at any point prior to the severe report, and those cases where several storms were near the point of severe weather occurrence, and it was difficult to identify which storm produced the severe weather.

Initially, 500 storms were identified, and out of those, 89 storms were deemed eligible to be included in this study. These included 64 severe thunderstorms. Twenty-five had severe hail of 1.88 cm or larger and 39 had wind gusts in excess of 25 m/s. There were 25 non-severe control cases.

The control cases in this data set were storms that were fairly similar in appearance, structure and magnitude to the severe storms in the base reflectively data and needed to have occurred over relatively populated regions.

3. METHODOLOGY

Once all the storm dates were identified, Archive Level II data was obtained from radars throughout the Northeast. The storms were interrogated using the WATADS (Johnson 1998) software package. Each storm was cross sectioned and the following parameters were obtained: Maximum Convergence, Maximum Grid Vertically Integrated Liquid (VIL), Cell VIL, Maximum Reflectivity, Maximum Reflectivity Height, Echo Top, Storm Top, Storm Speed and Direction, Storm Volume, VIL Density, Probability of Hail (POH), Probability of Severe Hail (POSH), and the top of the 45, 50, 55, 60 and 65 dBz reflectivity levels.

Each parameter was collected for five volume scans before the time of the severe weather event (T-5), to one volume scan after (T+1). Each WSR-88D volume scan is typically five (six) minutes in Volume Coverage Pattern (VCP) 11 (21).

As the analysis of the data progressed, several parameters that showed little potential as warning criteria were removed from further consideration in the study. The control and severe events were compared for each parameter, for both the entire data set and for matched data sets of both severe and control events occurring the same event day.

Absolute Lead Time (ALT) for this study is the number of volume scans from the time stamp of the product, to the occurrence of the severe event. Effective Lead Time (ELT) is the number of volume scans that reflects the actual time from the event to radar operator notification for volume products. With all products, the time stamp is the beginning time of the volume scan, even though volume products are not generated until the end of the volume scan. Typically ELT is one volume scan less than ALT for volume products, and is more representative of what a warning forecaster would experience from product arrival till the severe event.

4. RESULTS

Several parameters demonstrated potential for increased warning lead time. Those that offered the most potential are discussed here, a full discussion of all potential warning parameters are covered in Eastern Region Technical Attachment 2002-03 at http://www.nws.noaa.gov/er/hq/ssd/erps/ta/ta2002-03.pdf

a. 45 dBz Echo Top

This is the first of five different reflectivity thresholds that were examined for usable signals as warning thresholds. The optimum CSI for this parameter occurred at 23,000 feet with a CSI of .816, POD was .906, and FAR .108. For this value the ALT was 1.69 volume scans or 8 to 10 minutes.

b. 50 dBz Echo Top

All storms in this study having 50 dBz reach or exceed 24,000 feet were severe. Optimum CSI for this parameter was .765 at or above (aoa) 20,000 feet. At this point POD was .921, and FAR .181. The full range is shown in Table 1. The ALT was 1.66 or 8-10 minutes.

c. 55 dBz Echo Top

This level appeared to be more definitive. Three of the control cases never reached 55 dBz. Of the remaining control cases that did reach 55 dBz, none of them extended above 20,000 ft.

Table 1. POD, FAR, CSI for 50 dBZ Echo Top AOA various thresholds in kFT.

Height (kft) at or above	**POD**	**FAR**	**CSI**
24	0.594	0	0.594
23	0.703	0.043	0.681
22	0.734	0.078	0.691
21	0.828	0.117	0.746
20	0.921	0.181	0.765
19	0.953	0.208	0.762
18	0.969	0.235	0.747

Optimal CSI for this parameter occurred for values at or above 18,000 feet with a CSI of .789, POD .875, and FAR .111. The full range is shown in Table 2. The ALT for reaching the maximum value in this parameter is 1.75 volume scans or 9 to 11 minutes.

Table 2. POD, FAR, CSI for 55 dBZ Echo Top AOA various thresholds in kFT.

Height (kft) at or above	**POD**	**FAR**	**CSI**
21	0.625	0	0.625
20	0.734	0.021	0.723
19	0.813	0.088	0.754
18	0.875	0.111	0.789
17	0.906	0.147	0.783
16	0.938	0.189	0.769
15	0.953	.208	0.762

d. 60 dBz & 65 dBz Echo Tops

Major changes took place by these levels. This data points to the fact that if a pulse storm is capable of producing reflectivities over 60 dBz, it is highly probable that its severe, and occurrence is a sufficient threshold.

e. Probability of Hail

POH did a credible job of identifying Pulse severe thunderstorms. The average lead time for the peak of the (POH) was 2.42 volume scans, and ELT was 1.42 volume scans (about 7-8 mins), and about 1/3 of the time this was at a 100% probability of hail. Severe cases in matched data sets exceed controls by 40 to 50% (Fig. 1).

None of the control cases exceeded an 80% probability of hail. Only 5 of 61 severe storms where this parameter was produced, had values below 50%. POH values aoa 70%, correctly identified 85% of the severe storms while only mis-identifying 20% of the control cases. For probability of hail values aoa 80%, severe storms were correctly identified 70% of the time and controls 12% of the time.

f. Probability of Severe Hail

Probability of Severe Hail (POSH) like POH did well in identifying pulse severe storms for both wind and hail events. There was a respectable amount of lead time with an ALT of 2.13 volume scans or 1.13 volume scans ELT from the point of the peak of POSH. Only (Fig. 2) two of the 25 control cases exceeded 20% probability of severe hail.

g. VIL Density

VIL Density was calculated to see if VIL Density was applicable with Pulse thunderstorms, and to provide additional validation to Blaes et al. (1998) and Amburn & Wolf (1997) for this parameters utility in the Northeast United States.

VIL Density is defined as the quotient of VIL (kg m^{-2}) divided by the Echo top (m) and then multiplied by 1000 to yield units of g m^{-3}. At first glance, the lead time for this parameter does not look impressive at 1.77 volume scans. If the lead time is based on reaching or exceeding a VIL Density of 3.28 gm^{-3}, the critical value determined in previous studies, then the ALT jumps to 2.88 volume scans. The ELT is 1.88 volume scans. This provides 9 to 11 minutes lead time.

VIL Density was originally devised as a way to predict hail size potential for thunderstorms. Data were calculated separately for severe hail, severe wind, and combined wind and hail. The 3.28 gm^{-3} threshold was met or exceeded in 59% of the wind cases with an ALT of 3.13 and ELT of 2.13 volume scans.

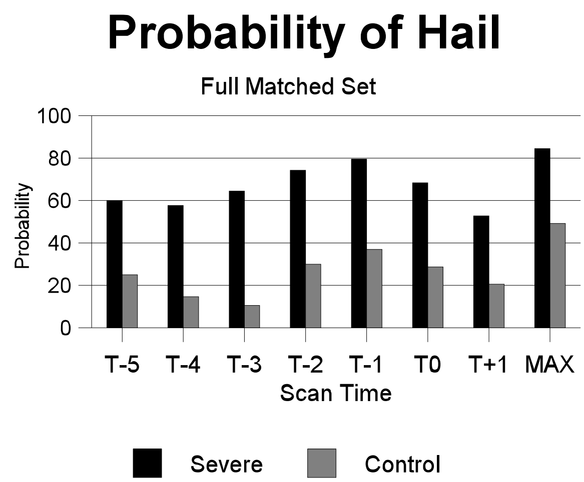

Fig.1. Probability of Hail from five volume scans prior to the time of severe weather to one volume scan after.

For the 25 control cases, the average peak VIL Density was 2.85. Confirming previous studies a VIL Density value equal to or greater than 3.28 gm^{-3} is a very useful warning tool for severe hail prediction. This study has shown, this VIL Density value is also very useful for predicting severe pulse thunderstorms.

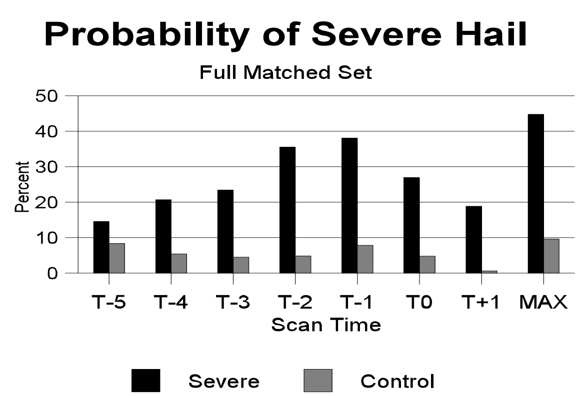

Fig. 2. Probability of Severe Hail (POSH) from five volume scans prior to time of severe event or peak of storm to one volume scan after.

5. CONCLUSIONS

While many of these parameters have potential as warning criteria for pulse severe thunderstorms, the most significant and useful were height of the Maximum Echo top of the 45, 50, 55, 60 & 65 dBz series, VIL Density, POH and POSH.

Table 3 shows the height top dBz where the optimal CSI is obtained, as well as the height that would represent a reasonable warning criteria for each dBz.

Table 3. Warning Criteria Suggestions. Height of Echo Top of dBz thresholds.

Echo Top dBz	Height AOA in Kft	Optimal CSI CSI/POD/FAR
45	23	.82/.90/.11
50	20	.77/.92/.18
55	18	.79/.88/.11
60	12	.57/.61/.09
65	any	

Table 4. Warning Criteria suggestions for Vil Density.

Parameter	AOA VIL Density kg/m3	Optimal CSI
Hail	3.28	.89
Wind	3.00	.61
ALL	3.00	.74

Table 4 shows the VIL density values corresponding to optimum CSI for hail, wind, and all events.

Using POH of 70% or greater and POSH of 20% or greater produces acceptable results for warnings, while limiting false alarms. For Echo Tops, severe cases showed values of 5,000 to 7,000 ft greater than the control cases in both averages of all data and matched data by event. Grid and Cell based VIL also show the Pulse severe storms have VIL values 2 to 3 times the controls, particularly when the values exceed 30 kg/m^3. The POD, FAR and CSI for Grid (Cell) VIL when the value exceeds 30 kg/m3 are .89,.12,.70 and (.76,.04,.71). This is another indicator to monitor from the warning desk.

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