9.11 PERFORMANCE OF THE WSR-88D BUILD 10 TORNADO DETECTION ALGORITHM: DEVELOPMENT OF OPTIMAL ADAPTABLE PARAMETER SETS

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1. INTRODUCTION

A new tornado detection algorithm (TDA) is included as part of the WSR-88D (Weather Surveillance Radar - 1988, Doppler) build 10 software release (late 1998). To improve performance of the previous TVS (tornadic vortex signature) algorithm, the TDA has been designed to detect a broader spectrum of 3D vortices (Mitchell *et al.* 1998). Even though the name of the algorithm has changed from TVS to TDA, the new TDA algorithm continues to identify TVSs (Brown *el al.* 1978). The thresholds suggested by Brown have been lowered as additional data have been analyzed in recent years.

The WSR-88D build 10 software release contains a modification to the velocity dealiasing algorithm (VDA) to optimize TDA performance (David Zittel, Operational Support Facility (OSF) Applications Branch, personnel communication). Velocity data set to missing by the VDA are restored using best guess values. All data cases evaluated in this study employed the build 10 dealiasing scheme. Also, this performance study does not account for velocity dealiasing, range folding errors, and noisy velocity fields. Performance figures reported here represent WSR-88D system performance as a whole (data ingest, clutter filtering, velocity dealiasing, and algorithm output.)

Initial studies at the OSF and National Severe Storms Laboratory (NSSL) revealed TDA has an overall critical success index (CSI) near 0.30, much higher than the previous WSR-88D TVS algorithm (CSI = 0.03). The new TDA also detects a greater number of locally intense vortices not associated with tornadoes. These non-tornadic detections are mitigated by adjusting three adaptable parameter values: minimum 3D feature low altitude delta velocity value (LADV), minimum TVS delta velocity value (MLDV), and minimum 3D feature depth (depth). This paper discusses these parameters, the optimization process, and summarizes findings for a large database of tornadic and non-tornadic circulations.

2. ADAPTABLE PARAMETERS

The build 10 TDA uses 30 adaptable parameters to specify program memory limits, modify data processing thresholds, and establish criteria for detecting 2D (2-dimensional) and 3D vortex features. Three of these 30 adaptable parameters filter 3D vortices by depth and gate-to-gate velocity difference.

The LADV value (TVS classification criterion) specifies the minimum gate-to-gate velocity difference allowed at the lowest elevation angle in a 3D vortex. The MLDV value (TVS classification criterion) specifies the minimum gate-to-gate velocity difference allowed anywhere within a 3D vortex. (The TDA requires **either** the LADV value **or** the MLDV value to be greater than a specified threshold to identify a TVS signature.)

The depth value specifies the minimum depth allowed for a 3D vortex to be identified as a TVS. By systematically adjusting the values of these three adaptable parameters, TDA performance was optimized for several convective data sets.

3. PERFORMANCE OPTIMIZATION STUDIES

3.1 Data sets

Scientists from the NSSL and the OSF analyzed 34 cases containing 2134 volume scans (approximately 194 hours of radar data) representing 168 tornadoes from many different areas of the United States. (Data available from the authors upon request.)

The thirty-four cases were categorized by storm type (15 isolated supercell cases, 13 squall line cases, and six tropical storm cases.) Several null cases (no tornadoes reported) were included in the isolated supercell and squall line categories. A composite data set was created by combining all the squall line and isolated supercell cases.

3.2 Composite data set

WSR-88D Level II archive data for each case in the composite data set were evaluated using WATADS (WSR-88D Algorithm Testing and Display System) (NSSL 1996). The relevant adaptable parameters (LADV, MLDV, and depth) were set to their lowest possible values (11 m s^{-1}, 11 m s^{-1}, 0 km, respectively). All algorithm detections were scored against *Storm Data*

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(NCDC 1992 - 1996) tornado damage reports as hits, misses, and false alarms using a time window scoring method (Witt *et al.* 1998). A separate program was used to evaluate algorithm performance for various combinations of LADV, MLDV, and depth.

An adaptable parameter engine, a program that systematically steps through combinations of adaptable parameter values was developed by NSSL to compute probability of detection (POD), false alarm ratio (FAR), and critical success index (CSI). Scientists from the NSSL and the OSF used the adaptable parameter engine to evaluate all TDA TVS detections in the composite data set from the lowest values of LADV, MLDV, and depth to arbitrary high values (80 m s^{-1}, 80 m s^{-1}, and 10 km, respectively). As LADV, MLDV, and depth values increased, fewer and fewer algorithm detections survived the threshold classification process.

Investigation of the composite data set revealed algorithm performance was least sensitive to depth values and more sensitive to LADV and MLDV values. Algorithm performance was optimized for depth in two steps: 1) identifying all depth values associated with the highest CSI's generated by the adaptable parameter engine, and 2) selecting the depth that minimizes FAR for the set identified in step 1.

From the composite data set, depth values (from 0.8 km to 2.9 km) were associated with the highest attainable CSI value of 0.22. Within this same range of depth, FAR values ranged from 0.55 to 0.66 and FAR was minimized when the depth adaptable parameter value was equal to 2.9 km.

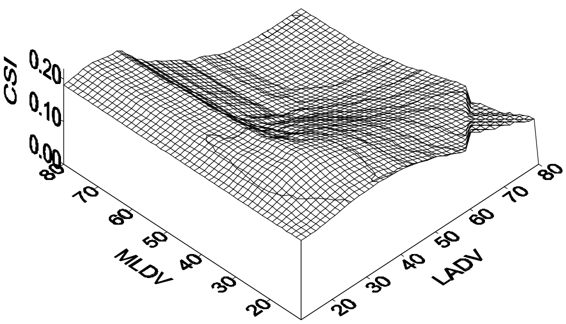

Figure 1. CSI as a function of LADV and MLDV for the composite data set. CSI is maximized for an LADV value of 29 m s^{-1} and an MLDV value of 30 m s^{-1}.

Figure 1, created from the composite data set, shows a 3D surface plot of algorithm performance, CSI, for an optimized depth of 2.9 km. Values of LADV and MLDV range from 11-80 m s^{-1} along the X and Y axes, respectively. Figures 2 and 3 show similar 3D surface plots of POD and FAR. Figures 1 and 2 show surfaces that are quite smooth (no steep mountains or valleys). The TDA is insensitive to small changes in LADV and MLDV.

The TDA performance in Fig. 1 is optimized when the LADV value is in the range of 23-29 m s^{-1} and the MLDV value is in the range of 25-36 m s^{-1}. Optimum TDA performance (highest CSI and lowest FAR) occurred when LADV was set to 29 m s^{-1}, MLDV was set to 30 m s^{-1}, and depth was set to 2.9 km.

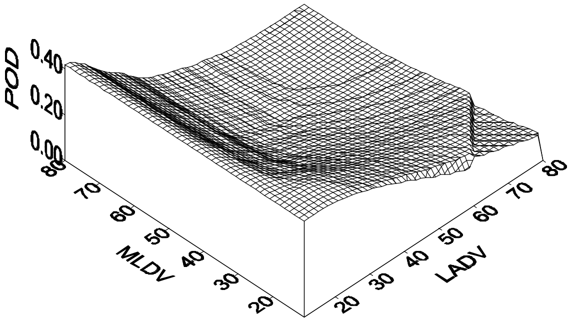

Figure 2. POD as a function of LADV and MLDV for the composite data set. TDA is insensitive to small changes in LADV and MLDV.

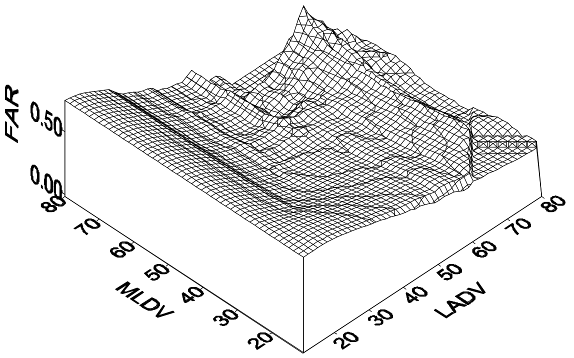

Figure 3. FAR as a function of LADV and MLDV for the composite data set. The FAR is high, but smooth at low values of LADV and MLDV; FAR minimizes for intermediate LADV and MLDV values, and then FAR becomes large agin.

Note the structure in the FAR surface (Fig. 3) for LADV values between 50 m s^{-1} and 80 m s^{-1}. High FAR values occur when LADV equals 50 m s^{-1}, for example, and MLDV ranges from 50-80 m s^{-1}. Either an LADV value over some threshold (50 m s^{-1} in this example) **or** an MLDV value over some threshold (50 m s^{-1}) is needed to declare a TVS. Few TDA detections meet the LADV threshold of 50 m s^{-1}. Some TDA detections meet MLDV TVS criteria (50 m s^{-1}); therefore, the MLDV parameter becomes more important and more false alarms are observed. As MLDV thresholds increase to relatively high values (50-80 m s^{-1}), no TDA detections meet MLDV TVS criteria, there are no false alarms, but also, there are no correct detections and CSI tends toward 0.

3.3 Isolated, squall line, and hurricane data sets

The same procedures used to determine optimum values of LADV, MLDV, and depth for the composite data set were applied to an isolated supercell data set, a squall line data set, and a tropical storm data set. (Data available from the authors upon request.) Table 1 shows LADV, MLDV, depth values, and corresponding performance values (hits, misses, false alarms, POD, FAR, and CSI) that maximize TDA's CSI and minimize FAR for each data set. Performance of the pre-build 10 WSR-88D TVS algorithm is listed at the far right for comparison.

3.4 Minimized parameter set

Several NWS forecast office personnel expressed an interest in maintaining the very low false alarm ratio associated with the old WSR-88D TVS algorithm. In an attempt to mimic performance of the prebuild 10 TVS, critical success indices were calculated using combinations of LADV, MLDV and depth (Fig. 1) to find which combination produced a CSI near 0.08 and minimized FAR. The sixth column of Table 1, Minimized Parameter Set, lists an adaptable parameter set that performs similar to the old TVS algorithm (POD ~ 0.03, FAR ~ 0.05, CSI ~ 0.03). Use of this parameter set is not recommended.

3.5 False Alarms

Compared to the prebuild 10 TVS algorithm and the minimized parameter set, the TDA appears to have a high false alarm ratio for the composite, isolated supercell, squall line, and hurricane data sets. Several factors contribute to an impression of too many false alarms.

A false alarm is defined as a TVS detection not associated with an observed tornado. If a tornado occurs at night or in a low population density area, TDA may detect a strong circulation, but the detection is labeled false alarm because the tornado is not observed. Just as often, strong vortices are observed on radar, but do not produce tornadoes.

The new TDA algorithm often identifies more than one TVS detection within the same storm scale circulation; consequently, up to half of the false alarms are of no importance because forecasters are notified more than once that a particular storm cell contains a 3D vortex.

False Alarm Ratio is calculated relative to the total number of hits and false alarms. For example, a FAR of 0.50 results if two TVSs were detected and one was a

Table 1. Optimized adaptable parameter values and TDA performance for various convective data sets. The 2 right hand columns are based on the composite data set.

Optimized (CSI and FAR) Parameters and TDA Performance	Data Set				Minimized FAR Parameter Set	Old 88D TVS Algorithm Performance
	Composite	Isolated	Squall Line	Tropical Storm		
Depth (km)	2.9	3.1	1.6	2.0	7.0	NA
LADV (m s^{-1})	29	27	27	14	45	NA
MLDV (m s^{-1})	30	30	27	44	69	NA
Hits	221	178	59	15	20	NA
Miss	523	238	269	352	724	NA
False Alarms	358	139	202	5	1	NA
Total # Detections	579	317	261	20	21	NA
POD (%)	30	43	18	4	3	7
FAR (%)	54	44	77	25	5	8
CSI (%)	22	32	11	4	3	7

false alarm. When the number of detections are small, FAR is easily increased with a few detections not associated with a tornadoes.

4. SUMMARY AND CONCLUSIONS

Performance of the WSR-88D build 10 TDA was optimized by calculating POD, FAR, and CSI values for many combinations of LADV, MLDV, and depth. The combinations of adaptable parameter values that generated the best TDA performance (highest CSI and lowest FAR) were established for ground truthed data sets comprised of isolated supercells, squall lines, tropical storms, and a composite data set made up of isolated supercell and squall line cases.

TDA performed best on isolated supercells. Poorer performance and shallower optimized depths are noted for the squall line and tropical storm data sets. While not recommended for use, a minimized parameter set, performance similar to the old TVS algorithm, will be made available in build 10.

Overall average performance scores are reported here. Large variations exist from case to case. Some isolated cases had CSI values as high as 0.55 and as low as 0.17.

When using the TDA in the WSR-88D build 10 software release, forecasters can modify LADV, MLDV, and depth adaptable parameters based on expected storm type. With build 10 software, forecasters have some idea of what performance to expect from TDA in each meteorological situation.

It is important to note that the parameter sets presented in Table 1 do not represent actual parameter sets for field use. This paper illustrates the procedures used to develop parameter sets employed in build 10 software.

5. ACKNOWLEDGMENT

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6. REFERENCES

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