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MODIFYING THE MESOCYCLONE DETECTION ALGORITHM: THE MISSING LAKE COBBOSSEECONTEE MAINE TORNADO

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1. INTRODUCTION

Storm surveys indicate a strong tornado (F2) struck Lake Cobbosseecontee, while under the radar umbrella of the Gray, Maine (KGYX) Weather Surveillance Radar - 1988 Doppler (WSR-88D) on 8 July, 1996 (Fig. 1). Sounding data and WSR-88D images revealed this convection to be characterized as a mini-Supercell (Grant 1996). The Mesocyclone/Tornado Vortex Signature Detection Algorithm (MTA)(National Weather Service 1991) identified mesocyclones, however not during the storm's tornadic stage. Also, the MTA did not identify a tornado vortex signature (TVS) during this event, or any other, since the acceptance of our Doppler radar in 1994.

The absence of a TVS detection within such a structurally organized cell presents serious implications for operational meteorologists. Tornadoes of this magnitude are climatologically rare in Maine, a state that has yet to receive an F3 tornado and averages only one tornado every two years (National Severe Storms Laboratory 1990). This investigation will use a conservative approach to discover the minimal thresholds necessary to trigger a TVS for the 8 July, 1996 event, by manipulating MTA thresholds using the WSR-88D Algorithm Testing and Display System (WATADS) (Mckibben 1996).

2. THE MTA - A BRIEF OVERVIEW

A recent study employed WATADS for algorithm testing, by altering MTA parameters in an attempt to improve mesocyclone and tornado detection by the WSR-88D (Tipton 1998). Currently, WSR-88D software Build 9.0 employs a threshold pattern vector (TPV) default value of 10. In this case, if at least 10 pattern vectors are found in close proximity, the MTA will identify a circulation. Three dimensional processing then links 2-D features from one elevation angle to another, classifying the resulting 3-D feature as either uncorrelated shear or a mesocyclone. Algorithm mesocyclones are detected when two or more symmetric 2-D circulations are identified at different elevation angles. If a mesocyclone is detected, the MTA further compares radial shear data against threshold TVS shear (TTS). If TTS criteria are met, then the mesocyclone is classified to contain a TVS (National Weather Service 1994). The TVS will likely be positioned within the mesocyclone area of symmetry.

Another threshold set by the MTA is called a percentage parameter (PCT). PCT defines the TVS search area beyond the diameter of the mesocyclone. The MTA default value for PCT is 5 percent. In this case, the MTA will expand the search for a TVS 5 percent beyond the diameter of the mesocyclone (Unit Radar Committee members did not have permission to change PCT during this publication).

Initially, it was hypothesized that the significantly tilted Lake Cobbosseecontee cell caused a threshold pattern vector test failure. If these thresholds were lowered, fewer close proximity pattern vectors would be required and the MTA may detect smaller scale circulations. Since March 1995, the Operational Support Facility (OSF) provided all WSR-88D sites the authority to change TPV, ranging from 6 to 10 (OSF 1995).

"Manual" identification techniques developed at the National Severe Storms Forecast Laboratory and presented at the WSR-88D Operations Course in Norman, Oklahoma (National Weather Service 1994), established preliminary shear criteria for mesocyclone identification at 72 hr^{-1}. However, the 8 July, 1996 storm represented characteristics commonly associated with tornadic storms in the East, where the WSR-88D Storm Relative Motion products displayed rotation significantly less than National Severe Storms Laboratory default values (Kuhl 1995). During touchdown, the low-level rotational velocity peaked at only 19 kts at a distance of 26 nm from the radar. In March 1996, to improve the MTA severe weather detection in East Coast storms, OSF authorized all WSR-88D sites to vary TTS thresholds from 72 hr^{-1} to a minimum of 18 hr^{-1} (OSF 1996).

3. 8 JULY, 1996 TORNADO

a. Data/Methodology

Archive II data tapes were retrieved from the National Climatic Data Center and diagnosed using Operation Support Facility WATADS version 8.0 software. Environmental sounding data from Gray, Maine was input due to its close proximity to the Lake Cobbosseecontee region. A 5-h period of significant convection surrounding the 2200 UTC tornado touchdown time (hereafter known as volume scan T) was analyzed. Storm surveys indicated no additional tornado touchdowns occurred outside this window.

Between 1700 UTC and 2200 UTC, the WSR-88D was operating with Build 8.0 software, and with parameter settings of TPV=10, TTS=72 hr^{-1} and PCT=5%. With these settings, the MTA detected 4 mesocyclones, all outside the volume scans adjacent to T, with the alert nearest touchdown located east of the pendant at T+2. Therefore, as mesocyclone detections are a preexisting criteria for TVS alarms (Build 8 and 9 software), no TVS alarms were provided to the forecasters during the event. Thus, it became imperative that TPV and TTS default values be adjusted to see if MTA detection capabilities could be improved.

In addition, examination of velocity data from the lowest three elevation scans showed shear values of the mesocyclone were quantitatively similar to that of the TVS. Therefore, PCT terms were sequentially changed to determine the MTA's ability to distinguish between the mesocyclone and the TVS.

Similar to this study, Tipton held TPV values constant while changing TTS and vice versa. A balanced finding resulted as mesocyclone and tornado vortex signature detections increased, while false detections were minimized. His tests led to optimized thresholds for pattern vectors and shear values of 7 and 35 hr^{-1}, respectively.

To achieve our goals, the focus was to change pattern vector and shear thresholds to a minimal level where a TVS would be generated. This was a challenge, since only two confirmed tornadoes have occurred within the detection range of the Gray, Maine WSR-88D. During these events the cells were positioned at significant distances from the radar and base velocity data depicted weak shear within these storms. The MTA could not produce mesocyclones during tests despite any input threshold values. There were no other confirmed tornado events within the Gray, Maine WSR-88D coverage area available for inclusion in this study, although it is possible that additional unreported tornadoes occurred.

b. Findings

Storm Relative Motion and Velocity products from the Gray, Maine WSR-88D indicated the Lake Cobbosseecontee storm initially appeared as a weak rotational couplet at 2101 UTC, before briefly exhibiting bowing features in the reflectivity field in an unstable, sheared environment by 2106 UTC. Using TPV/TTS default values, the storm organized into a weak mesocyclone by 2118 UTC. Post analysis of Storm Total Precipitation products correctly displayed a right turning cell, when compared to linear projections generated by the Storm Tracking Algorithm product.

The MTA displayed multiple weak mesocyclones in a shear zone along the southern perimeter of the nondescript cell. By 2130 UTC however, this storm revealed many characteristics of a mini-Supercell. Reflectivity images showed a pendant emerging along a rear flank downdraft with a classic V-notch upstream from a Bounded Weak Echo Region in the tilted cell. Similar to Grant's findings (Grant 1996), National Severe Storms Laboratory trend sets indicated the height of the mesocyclone and maximum rotational velocity lowered through T+1 (Fig. 2). Topography near Lake Cobbosseecontee was oriented parallel to the low-level ambient flow. However, terrain/shear time plots did not show evidence of increased storm rotational velocity due to topographical interactions as with other notable Northeast convection (Bosart et al. 1997).

WSR-88D MTA default values of TPV=10, TTS=72 hr^{-1} and PCT=5% were input into WATADS to verify the non-TVS output. As expected, results mirrored the WSR-88D findings (Fig. 3). This similarity could not be assumed however, since WATADS and the Radar Product Generator use slightly different algorithm codings and dealiasing techniques.

The minimal MTA values authorized by the Operational Support Facility of TPV=6 and TTS=18 hr^{-1}, were then tested. Mesocyclones remained undetected outside a 2112 UTC to 2217 UTC window. Therefore, subsequent tests using higher TPV and TTS thresholds were limited to this 65 min period.

Minimal thresholds flagged a mesocyclone in 11 of 12 volume scans, with a TVS alarmed at 2147 UTC (T-2), a 13 min lead time. An additional TVS was flagged at T+1. Unfortunately, range folding in the lowest elevation scan likely inhibited the MTAs ability to recognize a mesocyclone at T-2 and T-1. During this period pendants were clearly noted on reflectivity images.

Systematically changed pattern vector and shear threshold combinations were tested, including values "optimized" by Tipton (7 and 35 hr^{-1} respectively). Most attempts resulted in numerous mesocyclones, yet no TVS detections. However, despite range folding in the lowest elevation scan, pattern vector values of seven or less produced a TVS at T-2, when shear values were simultaneously lowered to a minimal 18 hr^{-1}. Therefore, shear appeared to be an inhibiting factor in triggering a TVS.

Next, a pattern vector of 7 was strategically combined with shear values until the first appearance of a TVS, which occurred at T-2 (Fig. 4). This conservative approach of gradually easing shear thresholds minimized the shear parameter at 24 hr^{-1} (Table 1). Nine of 12 volume scans produced at least one mesocyclone. If TTS was held at 24 hr^{-1} and TPV raised to 8, the TVS at T-2 and mesocyclone at T were eliminated. A less restrictive TPV=6 also required a shear value of 24 hr^{-1} to produce a TVS and was rejected since it did not meet our "optimization" goals.

Shear value tests using 18 hr^{-1} produced a second TVS at T+1. However, with a limited database, this low shear threshold was considered unacceptable to warning operations and a potential increase to false alarms. Therefore, TPV=7 and TTS=24 hr^{-1} were choice values, which are similar thresholds used by other northern climates such as Buffalo and Chicago (Lee 1997).

For each of the pattern vector and shear test combinations, the percentage term was modified from a range of 1% to 50%. This test did not affect the number of TVS alerts. Large values of PCT however, incorrectly displaced the TVS to the inflow notch, north of the surveyed storm track (Table 2). Therefore, the default percentage value of 5 percent was favorably accepted.

The MTA in Build 8.0 did not require TVS shears to be gate-to-gate. This northward displacement of the TVS symbol may have resulted due to the algorithm's inability to resolve TVS circulation when sampling the mesocyclone and the tornado. In this case, mesocyclone rotational values were similar to that of the microscale shear of the tornado. This, in part, may be due to beam widening and other factors such as sampling the relatively small microscale shear of the vortex (Brown et al. 1978).

4. CONCLUSIONS

A climatologically rare tornado within the Gray, Maine WSR-88D surveillance range struck undetected by the MTA. Considering the myriad of convection displayed on the PUP during the event, detection of additional mesocyclones or a TVS would have alerted focused duty forecasters to further examine the cell in question.

The initial hypothesis suggested that strong vertical shear led to extreme storm tilt. In this case, 2-D features would not be vertically associated by the MTA. Lowering the pattern vector threshold was necessary to identify the relatively small mini-supercell circulation. However, horizontal shear values were also found to be significantly lower than one may expect with a F2 tornado. Lastly, range folding inhibited the MTA at T-2 and T-1.

Conservative MTA thresholds of TPV=7 and TTS=24 hr^{-1} were determined to be "optimized" for mesocyclone/TVS detection during this event. Parameter considerations above these thresholds caused the absence of a mesocyclone in the volume scans adjacent to, and including T. Unreasonably low values of TTS thresholds alerted an additional TVS at T+1, but were considered unacceptable to warning operations due to the increased threat of false alarms. Percentage values had no effect on TVS identification, however larger values improperly redisplayed the TVS north of the damage path.

Future tornado events within the umbrella of the Gray, WSR-88D will allow for much needed database expansion. Preferably, weak tornadoes (F0-F1) should be examined using WATADS to further optimize MTA thresholds. However, caution must be maintained before reconfiguring thresholds, as minimization of false alarms, not necessarily optimization of mesocyclone/TVS detection, will raise forecaster confidence during the warning process. In addition, traditional TVS-based warning decisions need to be modified in tandem with algorithm modifications (Burgess et al. 1993).

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Table 1. MTA algorithm results with algorithm threshold settings of TPV = 10, while TTS = 72 hr^{-1} and PCT = 5% (MTA default values). Four mesocyclones were identified. The first mesocyclone was flagged at 42 minutes prior to touchdown. No mesocyclones were recognized outside cell #1.

Time (UTC)	**Meso Location**	**TVS**	**Remarks**
prior to 2118	none	none	no mesocylcone/TVS detections prior to 2118 UTC
2118	**S portion of cell**	none	cell ID #1
2124	none	none	
2130	none	none	
2136	**outside and S of cell**	none	
2142	none	none	
2147	none	none	range folding
2153	none	none	range folding
2159	none	none	
2200	none	none	**TORNADO TOUCHDOWN**
2205	none	none	
2211	**S portion E of pendant**	none	
2217	**S portion E of pendant**	none	
after 2217	none	none	no mesocyclone/TVS detections after 2217 UTC

Table 2. "Optimized" MTA algorithm results with algorithm threshold settings of TPV = 7, while TTS = 24 hr^{-1} and PCT = 5% . TVS detected at 2147 UTC. Lost two mesocyclones (when compared to sheet "V", where TPV=6, TTS =24 hr^{-1} and PCT=5%); including mesocyclone at time T. No mesocyclones were recognized outside cell #1. TVS was detected at 2147 UTC, 13 mins prior to touchdown with no MTA alarms during the actual touchdown.

Time (UTC)	**Meso Location**	**TVS**	**Remarks**
prior to 2112			no mesocyclone/TVS detections prior to 2112 UTC
2112	**S portion of cell**	none	cell ID #1
2118	**S portion of cell**	none	cell ID #1
2124	**E portion of cell**	none	
2130	E of pendant	none	
2136	2 detections - on each side of pendant	none	
2142	E of pendant	none	
2147	E of pendant	**YES**	range folding, 3-D correlated shear
2153	none	none	range folding
2159	none	none	lose meso at inflow
2200			**TORNADO TOUCHDOWN**
2205	none	none	lose meso at inflow
2211	S of cell	none	
2217	E of pendant	none	
after 2217	none	none	no mesocyclone/TVS detections after 2217 UTC

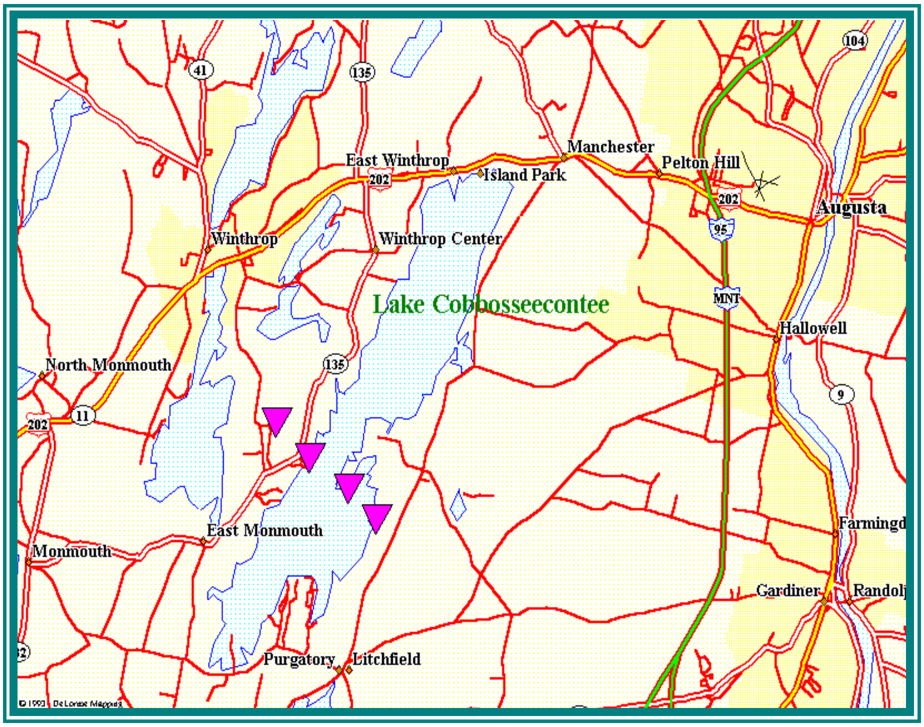

Fig. 1. Path of Lake Cobbosseecontee tornado, as determined by damage survey. Time of touchdown was 2200 UTC. Tornado moved from northwest to southeast.

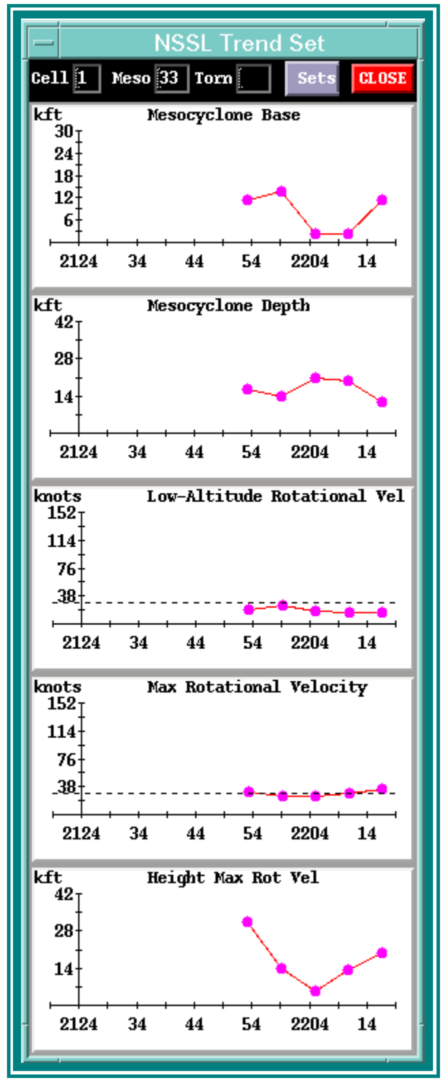

Fig. 2. WATADS Trends for Lake Cobbosseecontee mesocylcone. Note lowering heights of mesocyclone base and maximum rotational velocity.

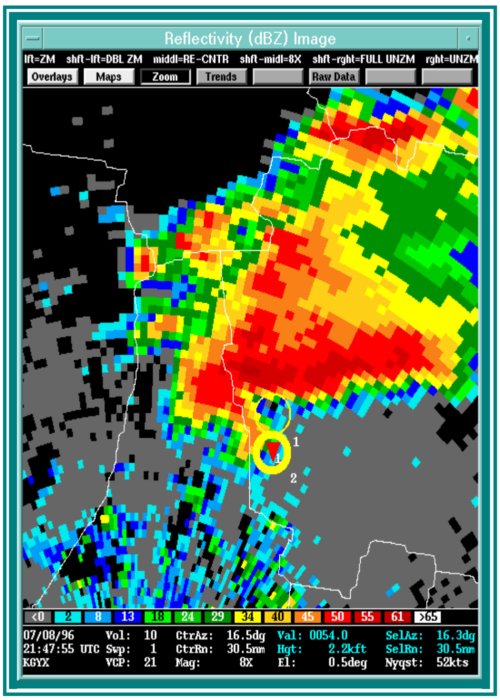

Fig. 3. The 0.5° base reflectivity image from the Gray, Maine WSR-88D showing TVS detection (red triangle) at 2147 UTC using MTA thresholds of TPV=7, TTS=24 hr^{-1} and PCT=5%. Land surveys indicate the tornado actually touched down at 2200 UTC. The thick yellow circle denotes a mesocyclone, while the thin circle is associated with 3-D uncorrelated shear.

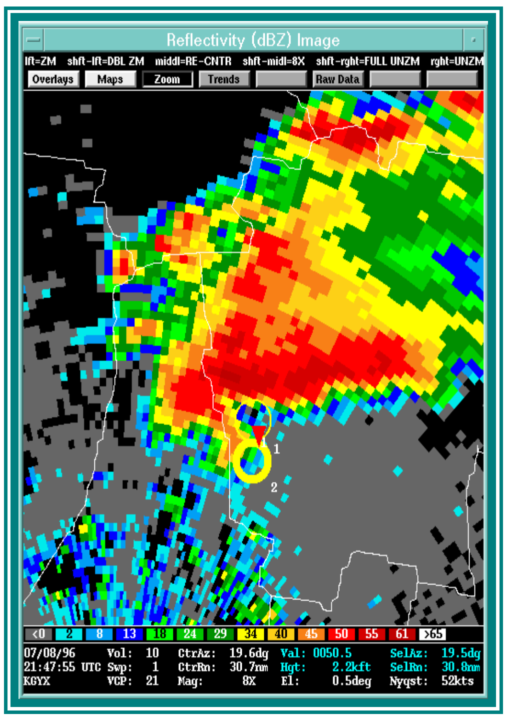

Fig. 4. Same as figure 3, except PCT=50%. TVS has been incorrectly displaced north into the inflow notch and into an area of uncorrelated shear.