12B.5 A REVIEW OF NEAR-STORM ENVIRONMENT AND STORM STRUCTURE CHARACTERISTICS OF THUNDERSTORMS THAT RESULTED IN FALSE ALARM WARNINGS ACROSS CENTRAL AND EASTERN IOWA

Rodney Donavon*
NOAA/National Weather Service Forecast Office
Des Moines, IA

1. INTRODUCTION

The National Weather Service's (NWS) mission is to protect the life and property of American citizens. One of the most important ways the NWS achieves this mission is by issuing crucial, life-saving tornado warnings. The effectiveness of NWS tornado warnings and the high false-alarm ratio (FAR) has recently been questioned. A FAR is defined as a tornado warning that was issued but not verified with a reported tornado. The NWS 5-6 February, 2008 Super Tuesday service assessments found that a tornado warning alone may not be enough to trigger a response from the public to seek shelter (NWS 2008). Furthermore, the NWS service assessment for the 22 May 2011, Joplin, Missouri tornado found that there may be a relationship between the high rate of false-alarm tornado warnings and the public becoming desensitized and complacent when tornado warnings are issued. Simmons and Sutter (2009) found a relationship between high local FAR and increased fatality rates.

On 1 October 2007, the NWS transitioned to a storm-based warning and verification system. Between the implementation of the storm-based system and the 2013 convective season, the national FAR has been 0.741. The NWS Government Performance and Results Act (GPRA) goal for FAR in FY2014 was 0.72; therefore, the NWS national FAR since the implementation of storm-based warnings would not meet this standard.

False-alarm tornado warnings during the storm-based era through the 2013 convective season from two NWS forecast offices; the NWS Des Moines, Iowa (DMX) and NWS Davenport, Iowa (DVN) were examined. During this period, the FAR at the NWS DMX and NWS DVN were below the national average at 0.705 and 0.726 respectively. Brooks (2004) stated that significant improvement in FAR could only be achieved through large reductions in probability of detection (POD). The goal of this research is to identify areas that can help improve FAR while not adversely impacting POD.

Numerous studies have focused on sounding-derived tornadic near-storm environment (NSE) including work by Johns et al. (1993), Rasmussen and Blanchard (1998), Rasmussen (2003) and Craven and Brooks (2004). More recently, NSE data represented by the hourly Rapid Update Cycle (RUC) (Benjamin et al. 2004) analysis grids have been used in studies by Thompson et al. (2003, hereafter T03), Davies (2004), Thompson et al. (2007, hereafter T07), Davies and Fischer (2009) and Thompson et al. (2012, hereafter T12).

The NSE is one of three factors that are considered during the warning decision process. Evaluation of volumetric radar data and the receipt of field reports are the other two factors. This study will focus on two of the three warning decision components. A comparison of the NSE and storm structure based on volumetric radar data between Iowa tornadic events (IATOR) and tornado warning false alarms (TORFAR) to determine if there are parameters that can be applied to lower the FAR. It is acknowledged that external factors such as tornado watches and spotter reports impact warning decisions however; these factors were not accounted for when reviewing false alarm data.

2. DATA AND METHODS

Data was collected for IATOR from 2004-12. The data was filtered to only include weak tornadoes rated EF1 or lower with the assumption that the NSE and radar signatures are more discernable for stronger tornadoes EF-2 or greater in strength. TORFAR data from 2005-13 was examined for the NWS DMX and DVN county warning areas and filtered to only include days when no tornado occurred. By selecting non-tornadic days, it can be assumed that the NSE was not as favorable for tornadic development when compared to days FAR warnings were issued and tornadoes also occurred. The latter scenario would imply that a tornadic NSE was present. The filtering process and data availability narrowed the sample size to 164 IATOR and 67 TORFAR.

Each event was assigned a convective mode following previous work done by Smith et al. (2012, hereafter S12). Eighteen non-supercell tornadoes, commonly referred to as landspouts, were removed from the database due to a much different formation process compared to supercells and QLCS events. Non-supercell tornadoes were categorized using NSE described by Baumgardt and Cook (2006) in addition to review of volumetric radar data and identified as non-mesocyclone tornadoes that formed during the convective updraft stage. The three convective modes used were right mover supercells (RM), quasi-linear

* *Corresponding Author's Address:* Rodney A. Donavon, NOAA/National Weather Service, Johnston, IA.
E-mail: Rodney.Donavon@noaa.gov

convective systems (QLCS) and disorganized thunderstorms. No left-moving supercell IATOR or TORFAR were found in this study. T12 assigned NSE data with each convective mode case from S12. Building upon S12 and T12, several aspects of volumetric radar based storm structure were also evaluated. Along with convective mode, storm structure parameters analyzed included rotational velocity strength and distance from the radar.

2.1 Near-Storm Environment

Data from the Storm Prediction Center (SPC) mesoanalysis system (Bothwell et al. 2002), which is based on hourly RUC analysis grids were used as described by T12. Data assigned to each case was based on the previous hourly analysis. The analysis included fourteen NSE parameters commonly used to assess tornadic potential. The data included various 100-hPA (mb) mixed-layer (ML) parameters including MLCAPE, MLCIN and lifting condensation level (MLLCL). In addition, bulk wind difference (BWD), storm relative helicity (SRH) including effective inflow layer-based parameters (T07), and composite parameters such as the significant tornado parameters (STP, Thompson et al. 2003 and the energy-helicity index (EHI) were analyzed.

2.2 Storm Structure

Volumetric radar data was reviewed for all IATOR and TORFAR previously defined. Several storm structure parameters were analyzed including mesocyclone properties such as rotational velocity strength in addition to overall storm evolution. The rotational velocity for IATOR were sampled at the time of initial touchdown in an attempt to distinguish between initial tornadic and non-tornadic circulations. In contrast, the strongest couplet was sampled during a period that included the immediate radar volume scan prior to tornado warning issuance through the expiration time of the warning.

3. RESULTS

RM represented a large majority of IATOR events and produced 132 of the 139 IATOR sampled. In contrast, of the 56 TORFAR thunderstorms with convective mode classified, 29 were classified as RM, 24 were classified as disorganized and the final 3 as QLCS. The disorganized storms exhibited either little discernable or very weak rotation which implies that a reduction in tornado warnings with these storms could help reduce FAR.

3.1 Near Storm Environment

The effective-layer STP and several of the components used to calculate the parameter were mostly useful to highlight environments more prone to tornadic development. The components for effective-layer STP include MLCAPE, MLCIN, MLLCL, effective-layer SRH (ESRH) and effective-layer BWD (EBWD). Note that the EBWD was not reviewed. A majority of the IATOR cases occurred with an effective-layer STP between 0.7 and 3 while the bulk of the TORFAR were in the 0.2-1.7 range. The median value 1.9 for IATOR was nearly double the median of 1.0 for TORFAR (Fig.1).

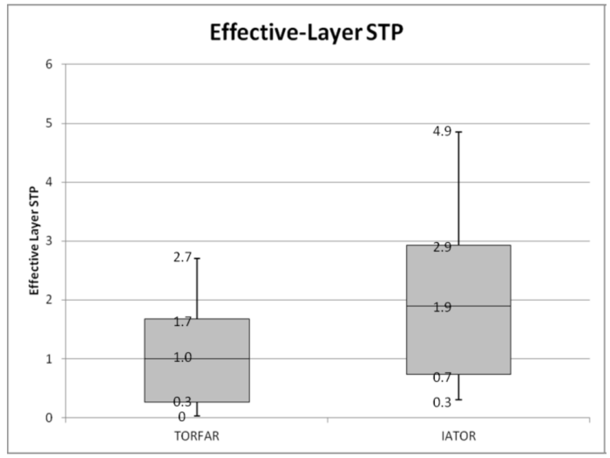

***Figure 1**: Box-and-whiskers plot of effective-layer STP for TORFAR and IATOR that show the 90th, 75th, 25th and 10th percentiles along with the median value.*

Two components of STP exhibited little to no skill distinguishing between IATOR and TORFAR environments. The MLCAPE median values for IATOR of 1599 J kg $^{-1}$ and 1567 J kg $^{-1}$ for TORFAR and the primary range of values was contained between 750 J kg $^{-1}$ and 2500 J kg $^{-1}$ (Fig.2). These results are consistent with T12 which suggests that CAPE is not a good discriminator for tornadic potential. MLCIN values were also comparable with magnitudes for a majority < 50 J kg $^{-1}$.

MLLCL values were a good discriminator between IATOR and TORFAR cases (Fig. 3). While the ranges of each were mostly contained between 500-1700 m, significant differences between the median values with IATOR at 802 m and TORFAR at 958 m. Less than one third of Iowa tornadoes occurred with a MLLCL greater than 1000 m while 43% of TORFARs were issued in the less favorable environment.

The ESRH was reviewed in addition to the 0-1-km SRH to account for the potential for overestimation during events when a near-surface layer existed due to inclusion of vertical shear within the stable layer (T07). The overall results for each were similar with the ESRH values slightly lower. To account for potential overestimation of the 0-1-km SRH, the ESRH results will be discussed. The median value 170 m^2/s^2 for TORFAR was less than the 225 m^2/s^2 for all IATOR (Fig. 4). More significantly, 94% of IATOR occurred with an ESRH ≥ 100 m^2/s^2 while 30% of TORFAR were issued with an

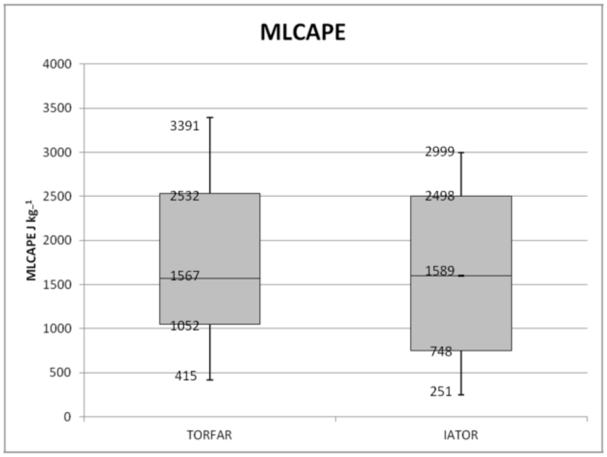

***Figure 2**: As is in Fig. 1, but for MLCAPE*

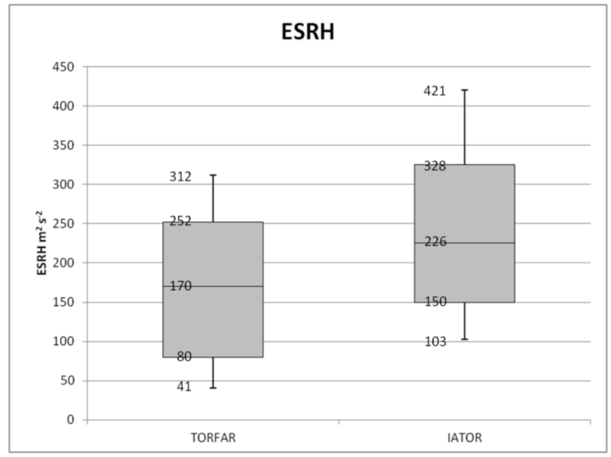

***Figure 4**: As is in Fig. 1, but for ESRH*

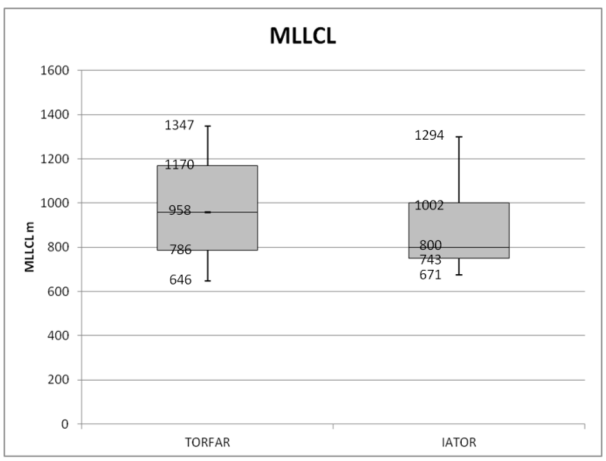

***Figure 3**: As is in Fig. 1, but for MLLCL*

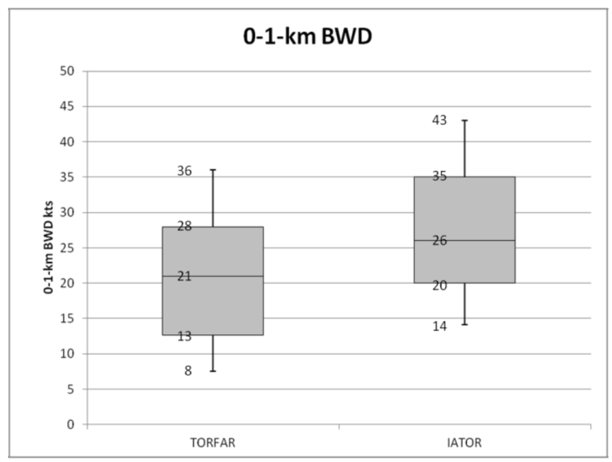

***Figure 5**: As is in Fig. 1, but for 0-1-km BWD*

ESRH < 100 m^2/s^2. Therefore, ESRH values ≥ 100 m^2/s^2 appear to be a possible discriminator between tornadic and FAR events.

The IATOR median value for 0-1-km BWD was 26 kts (13 m s^{-1}) which was nearly 5 kts (3 m s^{-1}) greater than TORFAR (Fig. 5). A NSE with the 0-1-km BWD < 20 kts (10 m s^{-1}) resulted in nearly half of the TORFAR events compared to only one quarter for IATOR. IATOR were rare with a 0-1-km BWD < 15 kts (11%) while one-third of TORFAR occurred in the weaker low level shear environment.

3.2 Storm Structure

The high percentage of disorganized storms in the TORFAR data had a sizable impact on the rotational velocity differences between IATOR and TORFAR. The median rotational velocity for IATOR was 77 kts (40 m s^{-1}) which was much stronger than 53 kts (27 m s^{-1}) for TORFAR (Fig 6). Only 3 of 67 TORFAR sampled had rotational velocities greater than the median value for IATOR. Tornado reports were not common with rotational velocities less than 50 kts (26 m s^{-1}) and only included 11% of the tornado reports while 45% of the TORFAR maximum rotation velocities remained below this threshold. A rotational velocity nomogram comparing rotational velocities for IATOR and TORFAR events is shown in Fig. 7.

Short lived shear couplets that developed during the supercell to bow echo transition phase accounted for 38% of TORFARs. The shear couplets formed as the cold pool advanced along the southern flank of the storm and interacted with the inflow region that migrated to the north. The couplets often rotated back into the cold air as the cold pool continued to surge ahead (Fig 8). The potential for the evolution of the bow transition into a QLCS line with a threat for mesovortex generation capable of producing tornadoes was low with these events. The 0-3-km shear magnitudes were often well below the 30 kt (15 m s^{-1}) criteria for tornado-producing mesovorticies found by Schaumann and Przybylinski (2012).

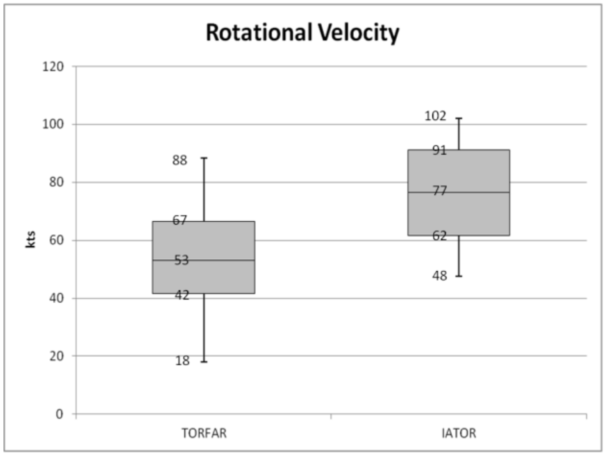

***Figure 6**: As is in Fig. 1, but for rotational velocity*

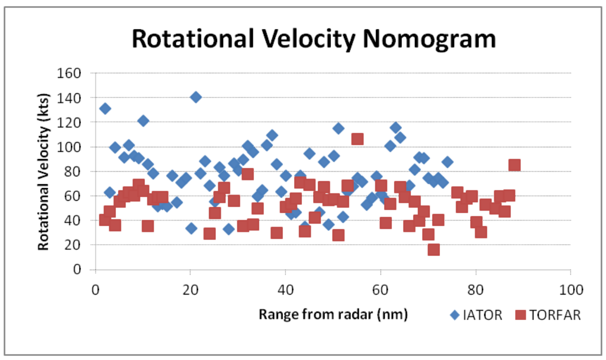

***Figure 7**: Rotational velocities for IATOR and TORFAR plotted compared to distance from the radar.*

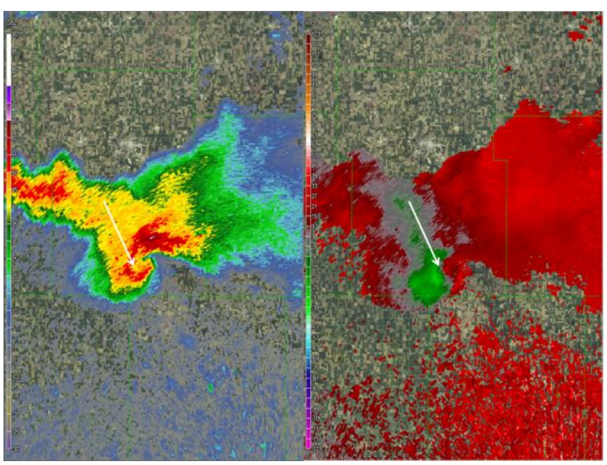

***Figure 8**: Supercell to bow transition with radar reflectivity on the left and storm-relative velocities on the right. At this time, the couplet is rotating back behind the surging cold pool at time a tornado warning was issued.*

4. SUMMARY AND CONCLUSSIONS

A review of NSE and volumetric radar data for IATOR and TORFAR data was completed in an effort to identify opportunities to lower the tornado warning FAR. An examination of fourteen NSE parameters commonly used to assess tornadic potential found low level predictors such as 0-1-km BWD, ESRH and MLLCL were superior discriminators between IATOR and TORFAR events. The effective STP uses two of these parameters, ESRH and MLLCL, in addition to MLCAPE, effective BWD and MLCIN. The effective STP was also a good discriminator with the median STP value for IATOR nearly 2 times greater than the median value for TORFAR.

Volumetric radar data was also reviewed to determine if storm structure and rotational velocity differences existed between thunderstorms that produced tornadoes and those that resulted in false alarm tornado warnings. While supercells produced a large majority of IATOR for the sampled period, only 52% of TORFAR were associated with supercells. A large portion of the TORFAR rotational velocities were below the 25^{th} percentile for IATOR and was a direct result of several disorganized thunderstorms that triggered tornado warnings. Thirty-eight percent of the TORFAR were associated with the supercell to bow transition phase with a tornado warning issued as the couplet had rotated back into the cold pool region.

A reduction the in FAR may be achieved with consideration of the NSE and volumetric radar data. Several TORFAR events occurred either within an unfavorable tornadic environment or with storm structure that was not conducive to a mesocyclone or mesovortex tornado. Many NWS offices incorporate a mesoanalyst during severe weather operations. The warning meteorologist should always be aware of the NSE.

5. Future Work

A more expansive dataset is required to incorporate a higher resolution convective mode classification. While a large percentage of Iowa tornadoes were associated with supercells, several of the events were associated with high-precipitation or low-topped supercells. The low-topped supercells in particular were occurred in weaker instability and higher sheared environments than the more classic supercells. Additional statistical analysis is required and will aid in developing stronger conclusions. Finally, external factors for each event should be examined. The spotter network reports are a vital part of the warning decision making process and must be accounted for.

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