Central Region Technical Attachment
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Forecasting High Impact Severe Thunderstorm Events

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1. Introduction

The Storm Prediction Center (SPC) defines a *significant* severe thunderstorm event as one containing hail greater than or equal to 2 inches in diameter and/or winds greater than or equal to 65 knots. Significant events, while accounting for only 4% of all events, are responsible for 52% of the dollar damages and 29% of all injuries and fatalities[3]. These "high impact" events have an impact far greater than the minimum severe weather threshold values of three-quarter inch hail and 50 knot winds.

Call-to-Action (CTA) statements have been in use by the National Weather Service (NWS) for over 25 years. CTA's are required within warnings, and CTA's inform the public of the potential hazards associated with the severe weather event. CTA's vary among offices, and can be divided into two general categories: 1) Those that contain generic safety information, and 2) those that contain specific threat information related to the severe thunderstorm. Troutman and Smith believe that providing specific threat information in the form of impact forecasts and CTA's better serve the public.

Currently, most Public Officials and Emergency Managers mitigate loss of life and property by enacting emergency plans, which can include such practices as staging of emergency personnel, activation of warning alarms, and sheltering. Statistics from the National Climatic Data Center (NCDC) show that 77% of all weather related injuries and fatalities are not associated with tornadoes[2], yet some emergency and local officials activate their plans only for tornado warnings.

Statistics from *Storm Data* during the period 1999 to 2001 show that 3,461 injuries and 177 fatalities were associated with severe thunderstorms. Given the importance of high impact events, this study focuses on the ability of the National Weather Service (NWS) to forecast and provide warning information for these events.

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3. Injury and fatality data obtained from NCDC. (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms)

2. Data Collection

The National Climatic Data Center (NCDC) and the NWS Verification Unit provided data for this study. The NCDC web site was used to access information for specific dates, events, and affected offices. Warnings were obtained directly from the NWS Verification Unit, which has archived electronic copies of warnings issued by NWS Offices dating back to 1997.

After viewing Severe Thunderstorm Warnings from all NWS offices, three offices were selected for this study. These offices were selected because of their consistent use of "impact" forecasts within their warnings, which convey the expected size of hail and/or the wind speed in the warned area. Examples of these warnings, can be found in Attachments A and B. Note in Attachment A, the forecast impact is found in the Call-to-Action (CTA) statement. The warning found in Attachment B places the forecast impact in the third bullet, similar to the current NWS warning format as described in NDS 10-511 (Attachment C).

3. Methodology

Severe weather reports were considered using 2 categories. The first category contained all severe thunderstorm events (hail greater than three-quarter inch and wind gusts greater than 50 knots). The second category, henceforth known as the "high impact" category, comprised all thunderstorm events containing hail greater than or equal to 1.75 inch diameter and/or winds greater than or equal to 61 knots. The events of the second category are intended to closely match the SPC significant thunderstorm event criteria.

Thunderstorm warnings were reviewed for the wind speed and/or hail size forecast in the warning text. These forecasts were compared to event data from *Storm Data* to compute verification statistics such as Probability of Detection (POD), False Alarm Ratio (FAR), and Lead Time.

Difficulties concerning the quality of the wind and hail data within *Storm Data* were encountered[4]. *Storm Data* contains many estimated wind reports, and due to the distances between measuring equipment, the maximum wind gusts are likely not recorded. It is also possible that maximum hail size may be under-reported due to NWS verification reporting biases. These biases may exist because verification phone calls by NWS warning forecasters often cease when the first verifying event is reported (Hales, 1993). The 10 mile/15 minute rule[5] may also account for the loss of some hail reports below 2.00 inches. Other data biases in *Storm Data* include day versus

4. An automated approach to the data was difficult, and much of the research was performed manually as each office's warning forecasts used differing formats and the data was in a non-delimited format.

5. The 10 mile/15 minute rule governs the reports which are archived for *Storm Data* and are used for verification purposes. Multiple reports of severe thunderstorm wind or hail events occurring less than ten statute miles and less than fifteen minutes from each other, and in the same county, are recorded as one event, with exceptions for tornadoes, winds 65 knots or greater, hail 2.00 inches or greater in diameter, any reports of injuries or fatalities, and crop or property damage greater than 500 thousand dollars.

night events, and reporting differences as a function of population density (Weiss, et al, 2002).

4. Findings

The authors' initial hypothesis presumed that the Probability of Detection (POD) for high impact events (HIPOD) would show better results than the total POD for severe thunderstorms, as these storms would likely have more pronounced radar signatures and storm environments. However, based on three years of data for the three NWS offices in the study, total POD was 0.79, compared with a HIPOD of 0.32.

a) Distribution of Events

Figure 1 shows that a total of 552 high impact events occurred within this study. Of that number, 358 (65%) of those high impact events were from thunderstorm winds.

Hail events by category are shown in Figure 2. Of 627 hail events, 187 (30%) of those events contained hail greater than or equal to 1.75 inches in diameter. Hail 2.00 inches or greater in diameter occurred just 29 times (5%) within the dataset.

It is important to note the grouping of hail around 1.75 inches in diameter. This grouping suggested a tendency toward reports of golfball-sized hail when actual hail size ranged between 1.00 and 2.00 inches. Given this grouping and the infrequency of hail reports above 2.00 inches, a baseline of 1.75 inch hail was used in this study.

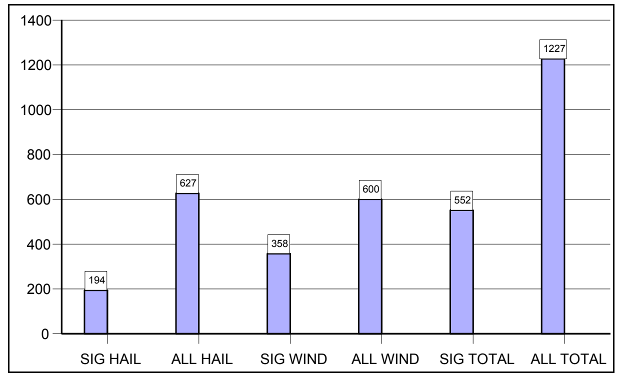

Figure 1. Significant events categorized by hail, wind, and a combination of both wind and hail for the period 1999-2001.

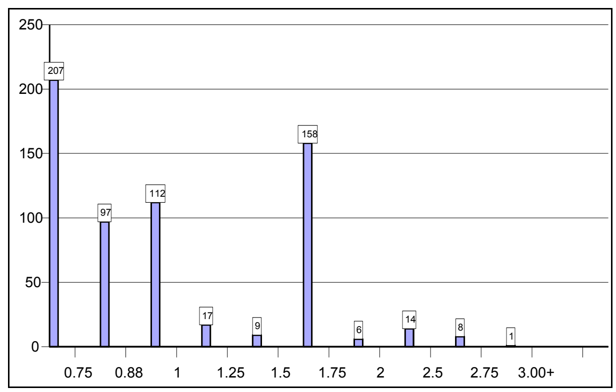

Figure 2: Hail size distribution for three Central Region Forecast Offices for the period 1999-2001.

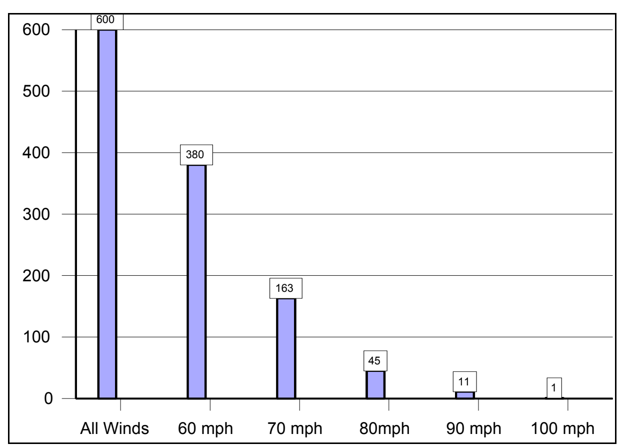

Figure 3: Estimated and measured wind speed distribution for three Central Region Forecast Offices for the period 1999-2001.

Figure 3 depicts the estimated and measured wind speed by category. Winds between 50 and 60 knots account for 380 (63%) of the reported events. Events between 60 knots and 70 knots accounted for 163 (27%) of all events, and winds measured or estimated greater than 70 knots accounted for 9 percent of all wind reports. A baseline of 61 knots instead of 70 knots was used in this study as only 9 percent of all wind events were 70 knots or greater.

b) Analysis of POD versus HIPOD

Average POD (figure 4) for the three NWS offices under study ranged from a minimum of 0.74 in 1999 to a maximum of 0.83 in 2000. The average POD for these three offices over the three-year period was equivalent to the NWS average for that same time (0.79). The HIPOD for the three NWS offices however, ranged from a minimum of 0.21 in 2000 to a maximum of 0.45 in 1999. The average of these years show HIPOD to be 41 percent lower overall than POD.

c) Analysis of FAR versus HIFAR

While not a primary concern, the authors did look at the HIFAR to investigate all aspects of the impact forecast. A large HIFAR was anticipated as the max hail size or wind speeds are, as discussed earlier, not often captured in the Storm Data.

Figure 5 depicts the FAR versus HIFAR. Values of FAR ranged from a low of 0.27 in 2001 to a high of 0.47 in 1999 and averaged 0.34 for the period, well

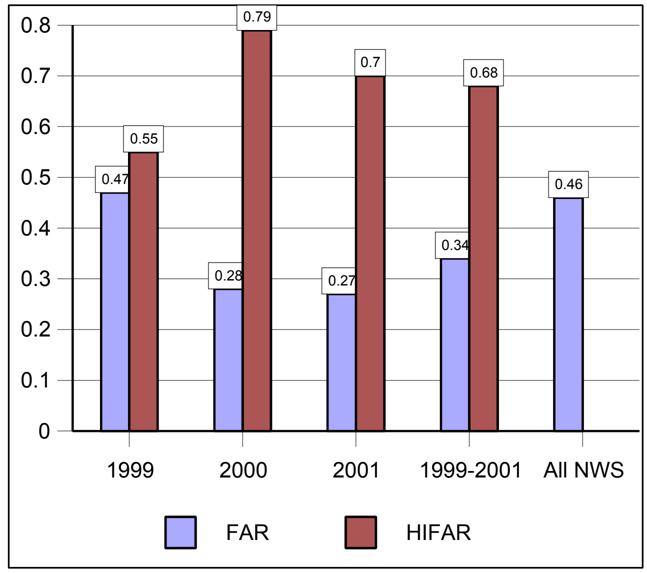

Figure 4: Probability of Detection and High Impact Probability of Detection for three Central Region Forecast Offices from 1999-2001.

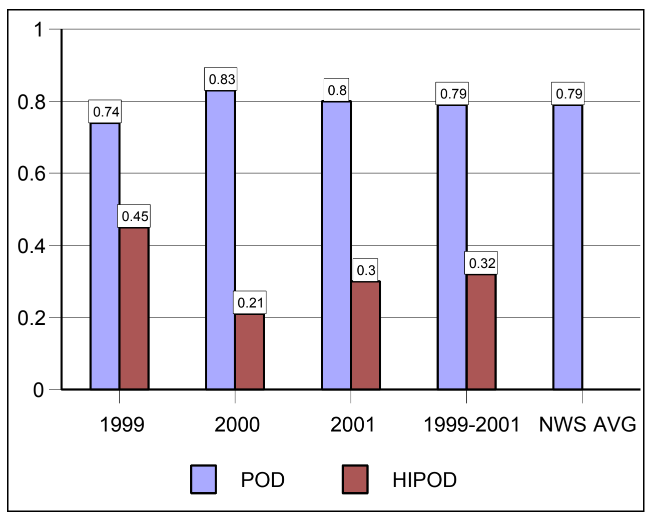

Figure 5: False Alarm Ratio and High Impact False Alarm ratio for three Central Region Forecast Offices for the period 1999-2001.

below the NWS average (0.46). HIFAR ranged from a low of 0.55 in 1999 to a high of 0.79 in 2000. The three-year average of HIFAR was 0.68, which is considerably higher than the overall national average FAR. These results indicate that the FAR for high impact events, (HIFAR) is greater than overall FAR.

d) Analysis of Warning Lead Time

Figure 6 shows the Average Warning Lead times for All NWS Offices and the combined three NWS offices in this study. This chart indicates that while lead time for the three offices was above the national average, lead time for high impact events was less than one third of both the national average lead time and study group lead time.

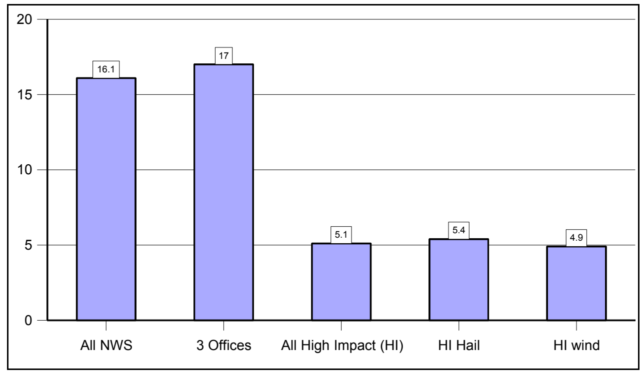

Figure 6: Average severe thunderstorm warning lead times for all of NWS Forecast Offices, the three Central Region Forecast Offices (all warnings) and the High Impact warnings from these 3 offices for hail, wind and combined .

5. Conclusions

The three NWS offices in this study have a lower FAR, equivalent POD, and lead times above the national average. A review of the warnings from these offices indicated a lower POD, higher FAR, and lower lead times associated with warnings issued specifically for high impact events. However, the POD for high impact events without consideration of the impact forecast during the study period was actually well above average (0.88). **Although warnings were in effect for these storms, the high impact thunderstorms more often than not arrived with a forecast of lesser impact.**

As stated in the introduction, high impact thunderstorm events produce a disproportionately high number of deaths, injuries, and damages. For this reason, attention should be focused on these significant thunderstorm events to improve our warning services and ultimately the protection of life and property. If accurate and reliable hail size, and perhaps more importantly thunderstorm wind speed forecasts were available, people might give the same attention to severe thunderstorm safety as they do tornado safety.

Accurate impact forecasts could also be used as the basis for including situation specific CTA statements. Such statements, as suggested by Troutman, Smith, and Rose (2002) are specific to a potential storm hazard. However, these impact statements are seldom used in NWS warning products. In fact, we found only three WFOs using specific situation CTAs in their warnings, and with only limited success.

6. Future Research

Significant severe thunderstorm events accounted for 52 % of the dollar damages and 29 % of all injuries and fatalities while making up only 4 % of all severe thunderstorm events.

National Weather Service Directive 10-

511 dated October 2002, provides a standardized format for the inclusion of an impact statement within severe thunderstorm warnings. This information is added as the last statement on the third bullet in the severe thunderstorm warning. An example of this format is found in Appendix C.

Research into specific hail size and thunderstorm wind gusts is needed to improve forecaster's ability to provide specific forecast values for impact statements in warnings. Use of the Weather Event Simulator will further enhance local research and the forecaster's ability to quickly and accurately choose the selection of the most appropriate impact statement for the severe weather situation.

Care and attention should be paid to the social response that such forecasts and Call to Action (CTA) statements bring. This is important because the addition of forecast impact and inclusion of threat specific information in the CTAs provide the general public with more information with which to make decisions. More information is usually positive; however, warnings are issued to elicit an immediate action, and therefore the information in a warning must be carefully considered so that it quickly ensures the correct response.

Acknowledgments:

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References:

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Troutman, Timothy. W., Smith, Richard and Rose, Mark. Situation Specific Call-to Action Statements. February 28, 2002 [last update] Available: http://www.srh.noaa.gov/FTPROOT/ssd/techmemo/sr215.htm. December 2001.

Weiss, Stephen J., J. Hart, P. Janish, 2002: An Examination of Severe Thunderstorm Wind Report Climatology: 1970-1999. 21st Conference on Severe Local Storms, San Antonio, Amer. Meteor. Soc.

Weiss, Stephen J., and M. Vesico, 1998: Severe local storm Climatology 1955-1996: Analysis of reporting trends and implications for NWS operations. *Preprints,* Second Symposium on Environmental Applications, Long Beach, Amer. Meteor. Soc., 152-157.

Appendix A

Here is an example of a severe thunderstorm warning containing an impact forecast in the CTA.

BULLETIN - EAS ACTIVATION REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE, ANYWHERE, XX
312 AM CDT SUN OCT 6 2002

THE NATIONAL WEATHER SERVICE IN ANYWHERE HAS ISSUED A

*** SEVERE THUNDERSTORM WARNING FOR...**
MARION COUNTY IN CENTRAL SOMEWHERE

*** UNTIL 415 AM CDT.**

*** AT 315 AM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A SEVERE THUNDERSTORM 4 MILES SOUTH OF ST CLAIR...OR ABOUT 13 MILES NORTH OF MILLERSVILLE...MOVING EAST AT 35 MPH.**

*** THE SEVERE THUNDERSTORM WILL BE...**

NEAR MILLERSBURG AROUND 345 AM CDT...

THE SEVERE THUNDERSTORM IS CAPABLE OF PRODUCING HAIL UP TO GOLFBALL SIZE AND WINDS IN EXCESS OF 70 MPH...

$$
NAME

Appendix B

Here is an example of a severe thunderstorm warning containing an impact forecast in the in the body of the warning (third bullet).

BULLETIN - EAS ACTIVATION REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE, ANYWHERE, XX
312 AM CDT SUN OCT 6 2002

THE NATIONAL WEATHER SERVICE IN ANYWHERE HAS ISSUED A

*** SEVERE THUNDERSTORM WARNING FOR...**
MARION COUNTY IN CENTRAL SOMEWHERE

*** UNTIL 415 AM CDT.**

*** AT 315 AM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A SEVERE THUNDERSTORM 4 MILES SOUTH OF ST CLAIR...OR ABOUT 13 MILES NORTH OF MILLERSVILLE...MOVING EAST AT 35 MPH. THIS SEVERE THUNDERSTORM IS CAPABLE OF PRODUCING HAIL GREATER THAN 1 INCH IN DIAMETER AND WINDS IN EXCESS OF 60 MPH.**

*** THE SEVERE THUNDERSTORM WILL BE...**
NEAR MILLERSBURG AROUND 345 AM CDT.

THE SEVERE THUNDERSTORM IS CAPABLE OF PRODUCING LARGE HAIL...DAMAGING WINDS...AND DEADLY LIGHTNING.

$$
NAME

Appendix C

Here is a sample of the format for a severe thunderstorm warning from the National Weather Service Instruction 10-511, effective November 2004. The instruction calls for impact statements in the body of the warning as well as impact locations.

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BULLETIN - EAS ACTIVATION (or IMMEDIATE BROADCAST) REQUESTED
SEVERE THUNDERSTORM WARNING (...CORRECTED as required)
NATIONAL WEATHER SERVICE CITY STATE
time am/pm time_zone day mon dd yyyy

THE NATIONAL WEATHER SERVICE IN CITY
HAS ISSUED A

* SEVERE THUNDERSTORM WARNING FOR...
  COUNTY ONE IN SECTION STATE (List warned counties)
  COUNTY TWO IN SECTION STATE (# Counties will match # counties in UGC Line)

* UNTIL hhmm am/pm time_zone (Expiration time of warning)

* AT hhmm am/pm time_zone... (Warning basis statement)
  (List impacts, including range of hail sizes and wind gusts)

* THE SEVERE THUNDERSTORM WILL BE NEAR... (Pathcast Version)
  LOCATION #1 AROUND hhmm am/pm time_zone...
  LOCATION #2 AROUND hhmm am/pm time_zone...

  OR

  LOCATIONS IMPACTED INCLUDE... (No Pathcast Version)
  LOCATION #1...
  LOCATION #2...

 (Impact Locations are mandatory, either pathcast or no pathcast version listed above)

CALL TO ACTION

LAT...LON (Mandatory list of latitude/longitude points outlining the forecaster-drawn area of greatest impact)

$$
FORECASTER NAME/NUMBER (OPTIONAL)
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