NOAA TECHNICAL MEMORANDUM NWS NSSFC-25

A DYAD OF PAPERS CONCERNING JOINT VERIFICATION OF SEVERE LOCAL STORM WATCHES AND WARNINGS DURING TORNADO EVENTS

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U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

National Weather Service
National Severe Storms Forecast Center

The National Severe Storms Forecast Center (NSSFC) has the responsibility for the issuance of severe thunderstorm and tornado watches for the contiguous 48 states. Watches are issued for those areas where thunderstorms are forecast to produce one or more of the following: (1) hailstones of 3/4 inch diameter or greater, (2) surface wind gusts of 50 knots or greater, or (3) tornadoes.

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No. 6 Severe Local Storm Warning and Event Summaries Available in AFOS. Preston W. Leftwich, Jr. and Lawrence C. Lee, January 1984, 10 p., (PB84 150291).

No. 7 Severe Thunderstorm Cases of 1984. John E. Hales, Jr. and Hugh G. Crowther, May 1985, 88 p., (PB85 210748/AS).

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PREFACE

Severe local storm watches and warnings are issued by the National Weather Service (NWS) to advise the public of impending threats from tornadoes, large hail and damaging thunderstorm winds. Both watches and warnings play important roles in accurately conveying such threats to the public. In the past, verification of these two products has been addressed separately. The following two papers discuss joint aspects of verification of severe local storm watches and warnings. The first paper documents which types of watches and warnings were in effect during all tornado events during 1982 - 1988. The second paper focuses on the role of watches in the overall warning process.

Earlier versions of both papers appeared in the preprint volume of the Twelfth Conference on Weather Analysis and Forecasting which was held October 2 - 6, 1989 in Monterey, California.

A COMBINED EVALUATION OF SEVERE LOCAL STORM WATCHES AND WARNINGS DURING TORNADO EVENTS

by

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ABSTRACT. The National Weather Service issues watches and warnings to alert the public to the threat of severe local storms. This study is based upon a tabulation of whether watches or warnings were in effect during tornado events during 1982 - 1988. Percentages of total events having the various combinations of watches and warnings were computed.

For the continental United States, there were 6200 tornado events during the period of study. Of these, 979 (15.8%) occurred when both a tornado watch and a tornado warning were in effect. There were 2165 events (34.9%) that occurred with neither a watch nor a warning in effect.

In order to address variations in tornado climatology, the continental United States were subjectively separated into six regions having similar meteorological characteristics. Percentages of tornado events having watches and warnings in effect were computed for each region. For example, the Southern Plains had the highest percentage (26.8%) of tornadoes occurring within both a tornado watch and a tornado warning. Also, the same region had the lowest percentage (24.6%) of tornado events with neither a watch nor a warning in effect.

Yearly percentages of events within watches or warnings were computed for five representative states. These states were Arkansas, Colorado, Mississippi, Oklahoma and Pennsylvania. In general, trends in percentages for these states reflected trends in national percentages.

1. INTRODUCTION

The National Weather Service (NWS) issues watches and warnings to alert the public to the threat of severe local storms. Severe local storm events include tornadoes, hail at least three-quarters of an inch in diameter, thunderstorm wind gusts of at least 50 knots, and thunderstorm wind damage. Tornado and/or severe thunderstorm watches and/or warnings will be issued when one or more of these events are expected to occur. Both separately and together, these products play an important role in conveying to the public the degree of threat posed by tornadoes or severe thunderstorms.

Verification of watches and warnings is a means of both evaluating public service provided by the NWS during severe local storm episodes and providing feedback to forecasters. Routine verification of severe local storm watches and warnings is an integral part of the NWS national verification program (NWS,1982). Past summaries of verification results, such as Kelly and Schaefer (1982), Grenier et al. (1988) and Leftwich (1989), have discussed watch and warning verification separately. This study addresses a combined analysis of severe local storm watches and warnings for tornado events during the period 1982 - 1988. That is, for each tornado event a tabulation was made of whether or not a watch and/or warning was in effect at the time of the tornado occurrence, and if so, which type.

The tornado event was selected for study for several reasons. Tornadoes consistently pose the greatest threat to life and property. Although inconsistencies have previously been identified in the collection of severe local storm reports (Kelly et al., 1985), such inconsistencies are not as evident in the reporting of tornadoes (Hales, 1987). The tornado event is a subject of much interest as the NWS begins implementation of advanced remote sensing technologies. Documentation of the current status of the watch/warning process will provide a basis for evaluating changes in procedures implemented in the future.

2. BACKGROUND

The first step in the forecasting of severe local storms by the NWS is the formulation of Convective Outlooks by the National Severe Storms Forecast Center (NSSFC) in Kansas City, Missouri. These outlooks describe areas in which conditions are expected to become favorable for development of severe local storms within the next 12 to 48 hours. Convective outlooks provide a common background for eventual issuances of watches and warnings. Because convective outlooks are not issued directly to the public, they will not be discussed in this study. Verification of these outlooks has been most recently discussed by Leftwich (1989).

Severe local storm watches are issued to the public from the NSSFC when atmospheric conditions have become favorable for severe local storms to occur within the next few hours. A watch typically encompasses an area of approximately 25000 square nautical miles and a time period of six hours. Tornado and severe thunderstorm warnings are issued to the public from local NWS offices throughout the United States when there is imminent threat from severe local storms. These warnings typically encompass an area of approximately two counties and a time period of one hour. Again, only tornado events during the period 1982 - 1988 have been considered in this study.

For purposes of this study, a tornado occurrence is defined as a documented tornado on the ground in a single county. This definition of a tornado event arises from a routine record-keeping procedure of having a tornado segment for each county to allow county-by-county verification of warnings (Grenier et al.,1988). Thus the tornado segments can be matched with the counties included within a warning and the area included within a watch. After tabulation of which type of watch/warning was in effect for each tornado event, calculation of the number and percentage of the total events falling in each category was done.

With two types of watches (tornado and severe thunderstorm) and two types of warnings (tornado and severe thunderstorm) issued, there are nine possibilities of coverage for each event. Combinations range from both a watch and a warning being in effect to neither being in effect. The most desirable situation, from both NWS and public points of view, is to have a tornado watch and a tornado warning in effect at the time of tornado occurrence. This provides maximum advance indication that there is a tornado threat and provides maximum time for preparation.

Figure 1 is a schematic table that displays codes indicating the distribution of tornado events in each of the nine combinations of watches and/or warnings. Such tables, are used to display data in the following section. Watches are denoted by a "W", warnings are denoted by a "G", tornado is denoted by a "1" and severe thunderstorm is denoted by a "2". Thus, the code "W1G2" denotes events contained within both a valid tornado watch and a valid severe thunderstorm warning. A "0" is used in combination with a "W" or "G" to denote that no watch or warning, respectively, was in effect. Sums for the various watch/warning types are found along the edges of the table ("TW" and "TG"). The total number of tornado events is denoted by "TEV". Because the number of tornado events varies from one time period and one geographical region to another, the percentage of events falling into each category is often a more meaningful value. These percentages are found by dividing the number in a particular category by the total number of events (TEV). Thus, they are a form of the Probability of Detection (POD) used in routine verification (Grenier et al., 1988).

	W1	W2	W0	TG
G1	W1G1	W2G1	W0G1	TG1
G2	W1G2	W2G2	W0G2	TG2
G0	W1G0	W2G0	W0G0	TG0
TW	TW1	TW2	TW0	TEV

Figure 1. Schematic table to display tabulations of tornado events in various combinations of watches/warnings. See text for explanations of category codes.

3. GEOGRAPHICAL VARIATIONS

The variations in tornado climatology across the United States have been well documented in the past (e.g., Kelly et al., 1978). Because tornadoes result from a variety of combinations of meteorological parameters from time to time and from one geographical location to the other, the difficulty in forecasting them also varies. These variations have been discussed previously by Ostby and Higginbotham (1982), among others. Also, variations in population density, spotter networks, and watch/warning philosophies (Hales, 1987) affect reporting of severe local storm events. Even so, these difficulties have not been as prevalent in regard to tornadoes as with hail and wind reports.

Figure 2 shows the results for the contiguous United States during the period 1982-1988. There were 6200 tornado events during the period of study. Of these, 979 occurred when both a tornado watch and a tornado warning were in effect. On the other hand, 2165 of these events occurred when neither a watch nor a warning were in effect.

	W1	W2	W0	TG
G1	979	177	564	1720
G2	479	177	350	1006
G0	986	323	2165	3474
TW	2444	677	3079	6200

Figure 2. Number of tornado events in each category for the United States during 1982 - 1988.

Next, the United States was subjectively divided into six regions having similar meteorological characteristics. These six geographical regions are depicted in Figure 3. The percentage of events occurring within each category was computed for each region and the contiguous United States as a whole. Results are shown in Table 1.

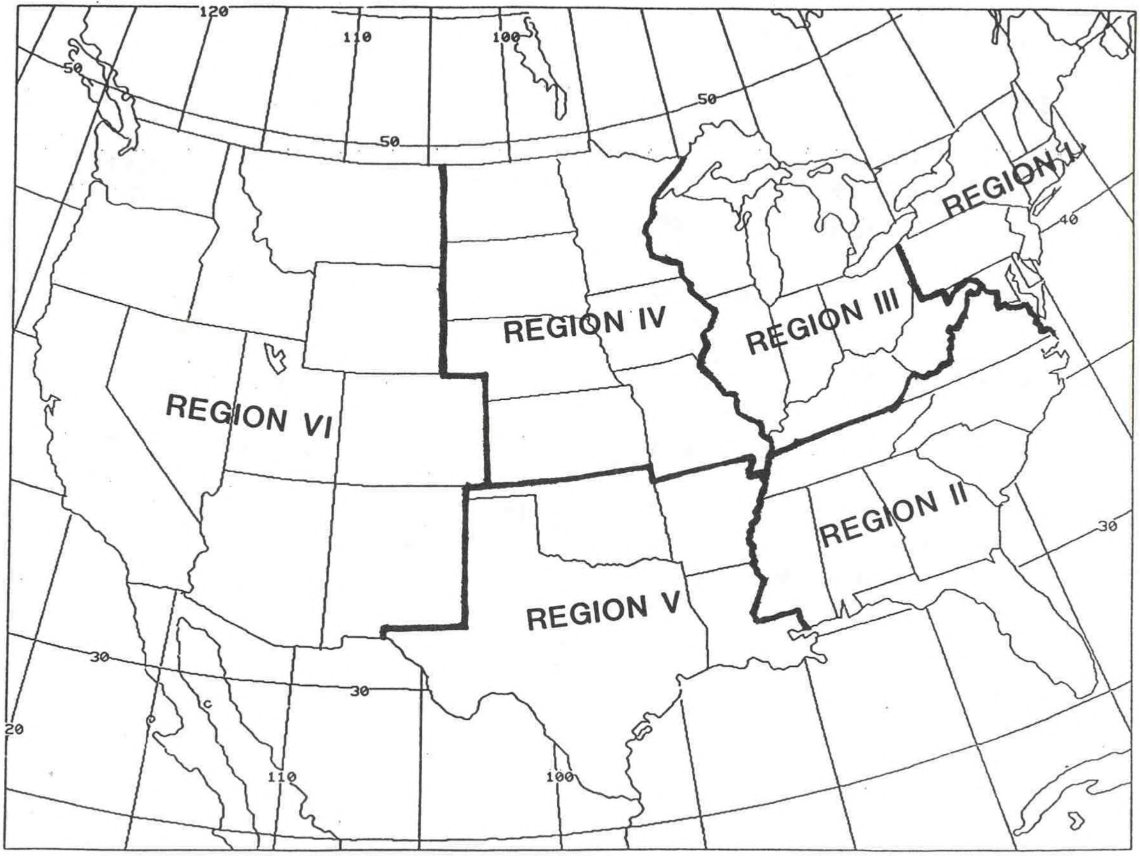

Figure 3. Geographical regions having similar meteorological characteristics.

Table 1. Percentages of tornado events within each category for the United States altogether and for the six designated geographical regions.

	W1	W2	W0	TG
G1	15.8	2.8	9.1	27.7
G2	7.7	2.8	5.7	16.2
G0	15.9	5.3	34.9	56.1
TW	39.4	10.9	49.7	6200

5.7	0.5	3.5	9.7
9.3	7.5	10.1	26.9
7.0	11.5	44.9	63.4
22.0	19.5	58.5	227

Region I

12.6	0.8	7.0	20.4
7.5	1.3	4.2	13.0
19.8	3.9	42.9	66.6
39.9	6.0	54.1	1251

Region II

10.7	3.1	7.3	21.1
7.7	3.2	5.9	16.8
15.9	9.4	36.8	62.1
34.3	15.7	50.0	742

Region III

14.4	5.2	10.1	29.7
8.4	4.6	6.2	19.2
17.0	6.0	28.1	51.1
39.8	15.8	44.4	1641

Region IV

brg diff.

26.8	2.7	11.1	40.6
8.3	1.5	5.5	15.3
16.5	3.0	24.6	44.1
51.6	7.2	41.2	1750

Region V

3.9	1.7	9.4	15.0
3.9	3.0	5.4	12.3
6.5	4.6	61.6	72.7
14.3	9.3	76.4	589

Region VI

Overall, 65.1% of the tornado events occurred within some type of watch or warning. Individually, tornado watches contained 39.4% of the events, while tornado warnings contained 27.7% of the events. A further focus on tornado watches and warnings shows 15.8% of the tornadoes occurring within both a tornado watch and a tornado warning. Also, the lowest relative percentages are seen for both severe thunderstorm watches and warnings. This reflects skill in distinguishing the potential for tornadoes from the overall severe thunderstorm threat. Similar results were discussed for severe local storm watches by Ostby and Higginbotham (1982).

As expected from climatology, Regions IV and V had the most tornado events during the seven-year period. Highest percentages of events within both a tornado watch and tornado warning were attained in these two regions. Of interest is the fact that five of the six regions had more than 55% of tornado events occur in some type of watch or warning. Clearly, Region V had the highest regional percentage (26.8%) of events in both a tornado watch and a tornado warning. In Region V the percentage in tornado watches (51.6%) and the percentage in tornado warnings (40.6%) were both the highest of the six regions. Region V also showed the highest percentage (11.1%) of tornadoes within tornado warnings when no watch was in effect. In this regard, Region IV was close behind with 10.1%. The highest percentage of tornadoes (19.8%) in tornado watches with no subsequent tornado warning was found in Region II. Percentages of tornadoes in severe thunderstorm watches (19.5%) and in severe thunderstorm warnings (26.9%) in Region I were both the highest in the Nation.

Percentages within tornado watches were higher than percentages in tornado warnings for every region except Region VI. Percentages in severe thunderstorm warnings were higher than percentages in severe thunderstorm watches for every region. This suggests that there has been greater skill in distinguishing tornado situations via watches than via warnings.

4. TRENDS

Table 2 contains selected percentages for each year of the period of study in order to identify any firm trends in watch/warning issuances. National percentages relative to both tornado watches and warnings (W1G1) were lowest in 1987. This can be at least partially attributed to the fact that 88% of the tornadoes that occurred during 1987 were of weak intensity (Leftwich, 1988). The overall percentages for either a watch or a warning (W or G) being in effect remained above 60% for the entire period.

Data for each year from five selected states (Arkansas, Colorado, Mississippi, Oklahoma, and Pennsylvania) follow the national data in Table 2. Data for Pennsylvania depict typical

Table 2. Yearly percentages of tornadoes within watches/warnings for the United States altogether and for five selected states.

NATIONAL

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	1088	42.5	28.6	18.2	7.8	14.8	50.2	43.4	65.3
1983	988	42.1	29.9	17.7	10.1	14.3	52.2	44.2	67.0
1984	1026	39.5	37.7	18.7	5.4	19.9	44.9	57.6	69.9
1985	767	40.9	30.0	16.9	10.0	17.1	50.9	47.1	66.6
1986	791	32.8	30.9	14.8	14.4	17.0	47.2	47.9	65.1
1987	695	25.3	24.0	8.3	22.0	17.3	47.3	41.3	62.2
1988	770	41.8	22.6	14.2	12.5	14.7	54.3	37.3	63.8

ARKANSAS

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	84	72.6	50.0	38.1	0.0	20.2	72.6	70.2	89.3
1983	17	58.8	5.9	5.9	5.9	23.5	64.7	29.4	70.6
1984	29	62.1	48.3	34.5	17.2	13.8	79.3	62.1	86.2
1985	11	54.5	36.4	36.4	0.0	18.2	54.5	54.6	54.5
1986	3	66.7	33.3	33.3	0.0	33.3	66.7	66.7	66.7
1987	2	50.0	0.0	0.0	50.0	0.0	100.0	0.0	100.0
1988	21	81.0	42.9	42.9	0.0	14.3	81.0	57.1	85.7

63.7 30.4

COLORADO

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	58	10.3	15.5	1.7	13.8	15.5	24.1	31.0	46.6
1983	32	25.0	21.9	3.1	0.0	15.6	25.0	37.5	50.0
1984	42	17.1	22.0	7.3	24.4	19.5	41.5	41.5	53.7
1985	26	15.4	7.7	0.0	11.5	34.6	26.9	32.3	50.0
1986	21	33.3	9.5	9.5	14.3	14.3	47.6	23.8	52.4
1987	40	37.5	22.5	7.5	10.0	25.0	47.5	47.5	65.0
1988	48	29.2	22.9	10.4	10.4	10.4	39.6	33.3	47.9

MISSISSIPPI

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	21	23.8	23.8	4.8	0.0	9.5	23.8	33.3	42.9
1983	21	76.2	38.1	33.3	0.0	28.6	76.2	38.1	90.5
1984	21	52.4	33.3	19.0	4.8	28.6	57.1	52.4	71.4
1985	21	28.6	38.1	16.7	9.5	19.0	38.1	57.1	81.0
1986	48	37.5	18.8	12.5	25.0	14.6	62.5	33.3	66.7
1987	48	93.8	25.0	25.0	2.1	14.6	95.8	39.6	97.9
1988	67	74.6	40.3	35.8	3.0	14.9	77.6	55.2	82.1

OKLAHOMA

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	225	60.2	32.0	23.3	2.9	19.4	63.1	51.4	76.7
1983	188	61.9	55.4	42.4	12.0	16.3	73.9	71.7	87.0
1984	59	57.6	52.5	39.0	8.5	20.3	66.1	72.8	86.4
1985	37	43.2	43.2	27.0	13.5	16.2	56.7	59.4	78.4
1986	48	56.3	45.8	27.1	10.4	18.8	66.7	64.6	81.3
1987	23	26.1	21.7	4.3	26.1	21.7	52.2	43.4	65.2
1988	18	33.3	11.1	11.1	16.7	22.2	50.0	33.3	61.1

48.4 37.4

PENNSYLVANIA

YEAR	EVENTS	W1	G1	W1G1	W2	G2	Any W	Any G	WorG
1982	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	20	20.0	20.0	10.0	30.0	25.0	50.0	45.0	70.0
1984	11	0.0	0.0	0.0	0.0	54.5	0.0	54.5	54.5
1985	49	57.1	20.4	10.2	4.1	40.8	61.2	61.2	81.6
1986	7	0.0	0.0	0.0	14.3	14.3	14.3	14.3	14.3
1987	6	0.0	0.0	0.0	83.3	33.3	83.3	33.3	83.3
1988	6	0.0	0.0	0.0	33.3	33.3	33.3	33.3	33.3

results for an area having relatively few tornadoes, but experiencing a significant outbreak every few years. Colorado and Oklahoma are areas in which new technologies pertinent to the NWS severe local storm watch/warning program were being tested during at least part of the period of study. Arkansas showed a general decrease of tornado activity during this period, and Mississippi had a general increase in activity.

Trends in the state data followed those observed for national data and are representative of the geographical region to which each state was assigned. Each of the four states generally attained a rather high percentage of having some type of watch or warning in effect when tornadoes occurred. There do not appear to be firm trends in the percentages of tornadoes contained within watches or warnings that can be clearly separated from the degree of tornado activity each year.

5. SUMMARY AND CONCLUSIONS

This study presents a combined look at the percentages of tornadoes contained within valid severe local storm watches and warnings. Data were analyzed for the period 1982 - 1988. For each tornado event, a tabulation was made of which type of watch or warning was in effect at the time a tornado occurred.

The basic assumption is that the best public service is provided by the NWS when both a tornado watch and a tornado warning are in effect prior to a tornado event. Overall, this was accomplished for 15.8% of the tornado events. Tornado watches were in effect for 39.4% of the events, and tornado warnings were in effect for 27.7% of the events. One or the other of these were in effect for 51.3% of the cases. That is, in 51.3% of the tornado cases the NWS had a public product in effect that emphasized the threat of tornadoes.

Although severe thunderstorm watches and warnings do not emphasize the threat of tornadoes, they do alert the public to the threat of especially dangerous thunderstorms. For the Nation as a whole, lower percentages of tornadoes occurred within severe thunderstorm watches and warnings than occurred in tornado watches and warnings. This reflects an overall skill in distinguishing situations with the added threat of tornadoes. When severe thunderstorm watches and warnings are added, 65.1% of the tornado cases had either a valid severe local storm watch or warning in effect at the occurrence of a tornado.

When regional data are considered, the southern Plains (Region V) had the highest percentage of tornadoes in both a tornado watch and a tornado warning. In five of the six regions, a higher percentage of tornadoes occurred within tornado watches than within tornado warnings. In all six regions more tornadoes occurred within severe thunderstorm warnings than within severe thunderstorm watches. This suggests that there has been more skill in distinguishing tornado situations via watches than via warnings.

There appear to be no firm trends in percentages of tornadoes within watches and/or warnings that can be clearly separated from the annual variation in the number of tornadoes. On a national basis, the percentage of tornadoes contained within some type of valid watch or warning was greater than 60% throughout the period of study.

This study has documented statistics pertaining to the occurrence of tornadoes within severe local storm watches and warnings issued by the NWS. It is intended to establish background for future evaluations and to neither compare the severe local storm watch program with the severe local storm warning program nor to compare one NWS office with another. Although these results suggest more focus on the containment of tornadoes in tornado watches and warnings, detailed explanations of the variations observed in these data are beyond the scope of this study. However, stimulation of interest in further analysis of these data was a goal of the current study.

This study has focused on all tornadoes. Related analyses of these tornado data, "significant" events and the role of severe local storm watches in the warning process, are discussed by Hales (1989), which is Section III of this report. Also, the question of what events occur when a particular type of severe local storm watch and/or warning is in effect is a topic for future study.

6. ACKNOWLEDGEMENTS

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THE CRUCIAL ROLE OF TORNADO WATCHES IN THE ISSUANCE OF WARNINGS FOR SIGNIFICANT TORNADOS

by

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ABSTRACT. The tornado warning is the single most important severe weather product that the National Weather Service issues. Considerable effort is made to provide the information needed to issue a tornado warning as accurately and timely as possible. The tornado watch is a crucial ingredient in this support.

The objectives of this paper are to evaluate the services provided by the Watch/Warning program during the most dangerous tornado occurrences and to point out the important role the tornado watch plays in support of the tornado warning program.

For this study, only the significant tornados (killer plus F3 and greater tornados) were used for the period from 1982-88. Each of the significant tornados was checked on its inclusion in or close to a watch and in a warning; the type of each watch or warning and the lead time.

Whereas only about 40 percent of all tornados were in or near tornado watches, over 80 percent of the significant tornados were in or near tornado watches. Although the number of severe thunderstorm watches exceeds tornado watches annually, only about 5 percent of significant tornados were in severe thunderstorm watches. This indicates considerable skill in 1) discriminating between tornadic and non-tornadic severe weather threats and 2) forecasting for the significant tornado. Another surprising finding was that the mode of the lead time in tornado watches to significant tornado occurrence is 4 to 5 hours.

Significant tornados were preceded by tornado warnings in only about 38 percent of the cases studied. However of these warned significant tornados over 90 percent were preceded by tornado watches. This confirms the critical nature of tornado watch issuance in setting the stage for the timely warning. This is accomplished by creating a proper mind set in the field forecaster of the importance of the meteorology that is driving the tornado threat. Also it in many cases activates the public spotter networks, which in turn provide important feedback to the warning meteorologist. The findings of this study suggest that for the best public service it is critical that a tornado watch be in place prior to the occurrence of a significant tornado.

1. INTRODUCTION

The most important life saving public product the National Weather Service (NWS) issues is the tornado warning. However, issuing advance tornado warnings continues to be a very difficult task. Tornados are often impossible to detect on current NWS radars, and they occur infrequently in most sections of the country.

The NWS's current system (NWS, 1982) used to evaluate the accuracy of tornado warnings is inadequate for several reasons (Hales, 1987). Not the least of these is the fact that any severe event (tornado, wind damage, or large hail) will verify a tornado warning. This makes it impossible to use routine verification statistics to evaluate the quality of service provided by tornado warnings. really!

It is well known that most of the more significant (F3 and greater) and killer tornados are the result of strong meteorological forcing in the atmosphere. However, a large majority of the tornados are of the weak variety (less than F3) and are very difficult to detect by radar. These weak tornados complicate the evaluation of skill in the forecasting and warning system. To properly evaluate the NWS watch and warning program, the emphasis needs to be on the type of watches and warnings that were in effect when the killers and more significant tornados occurred as suggested by Hales (1987). Therefore, in this paper tornados are divided into three categories: (1) those that result in loss of life, (2) those that have the potential of resulting in loss of life and causing considerable damage (F3 and greater) and (3) all tornados together. Emphasis will be placed on "significant tornados", as defined by the first two categories. A parallel study by Leftwich (1989) analyzes the geographical variation and trends in combined watch/warning verification for all tornados during the period 1982-1988.

Routine verification (including past summaries of verification results) has treated watch (Leftwich, 1988) and warning (Grenier et al., 1988) verification separately.

This paper will consider tornados that occurred during the period 1982-1988. Figure 1 shows the annual distribution of the three categories of tornados that were evaluated. The significant tornados include the F3 and greater storms as well as any killer tornado. It is readily seen that the significant/killer tornados make up only a small percentage of the annual total. While there is some variation in tornado occurrence from year to year, the annual range in the significant events is much greater. For example, 1982 and 1984 had over 300% more significant tornados than each of the years 1985-1988, while for all tornados 1982 and 1984 had only about 30% more.

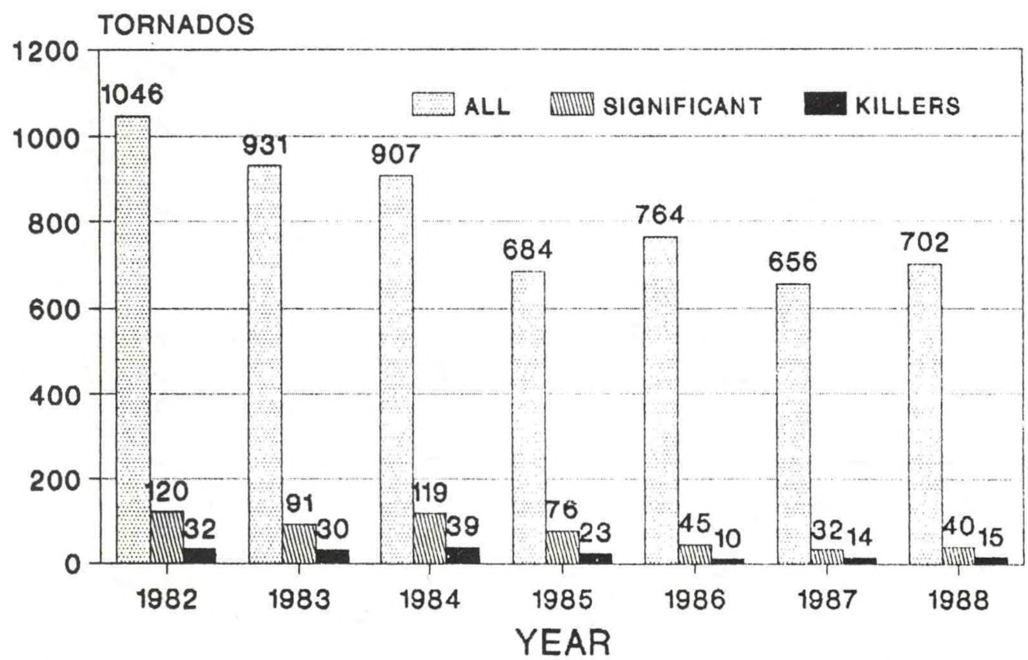


Figure 1 Annual tornados, all, significant and killers, 1982-1988.

For purposes of this study, a tornado occurrence is defined as a documented tornado in a single county. For example: if one tornado has a track that affects three counties, it is counted as separate tornado occurrences for each of the three counties. This definition of a tornado event arises from the need to allow for county-by-county verification of warnings (Grenier et al, 1988). Thus the tornado segments can be matched with the counties included within the warnings and the area included within a watch.

2. TORNADO WARNINGS AND WATCHES

From an examination of the probability of detection (POD) (Fig 2) of tornados by tornado warnings there is little difference in skill in warning for significant tornados versus all tornados. This is because most tornado warnings are based on sightings. Any time a tornado of any intensity occurs, there is only about a 30% chance of its being preceded by a tornado warning.

While little skill is noted in warning for the significant versus non-significant tornadoes, there is considerable skill in issuing watches for significant tornados. Figure 3 shows that there is almost twice the chance that a killer tornado will be forecasted versus non-killer tornados. Skill in forecasting significant tornados (Figure 4) is even a little better than forecasting the killer tornados with an average of 71% of all significant tornados occurring in tornado watches versus 35% of all other tornados.

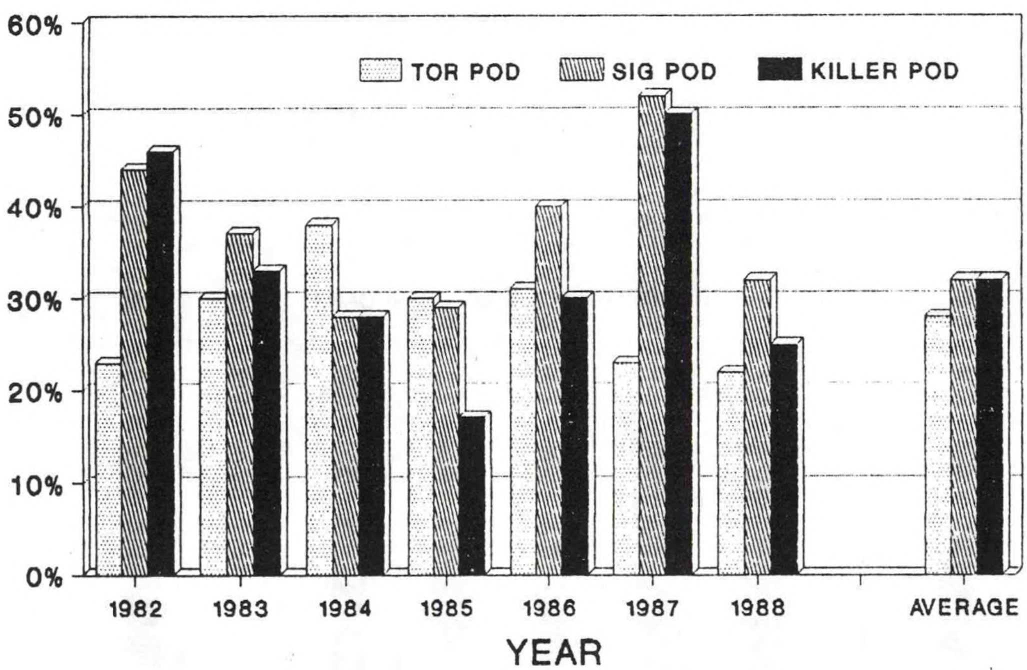


Figure 2 POD of tornados in tornado warnings, all, significant and killers, 1982-1988.

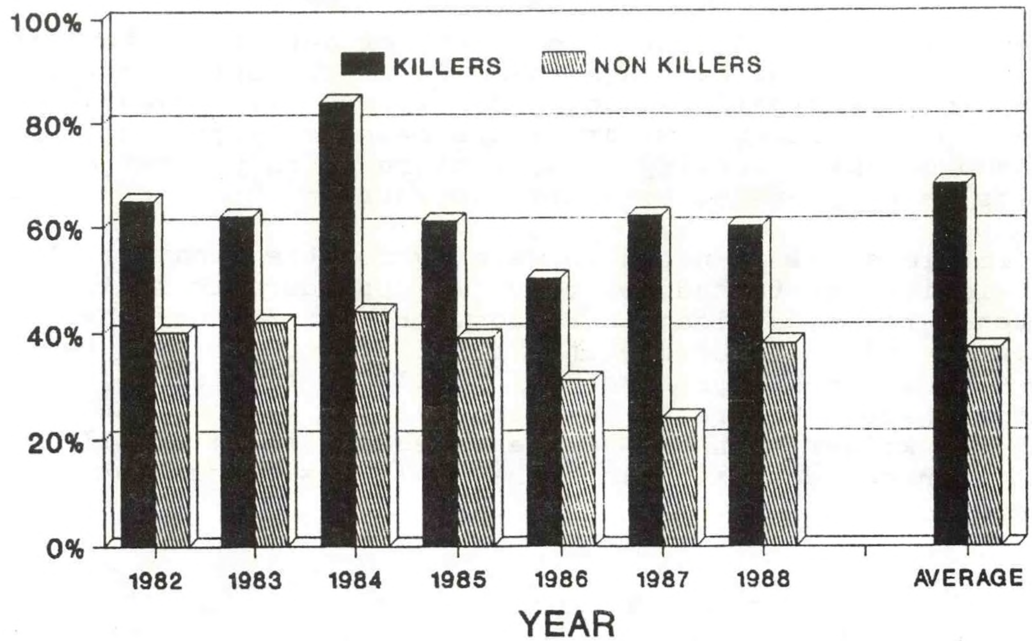
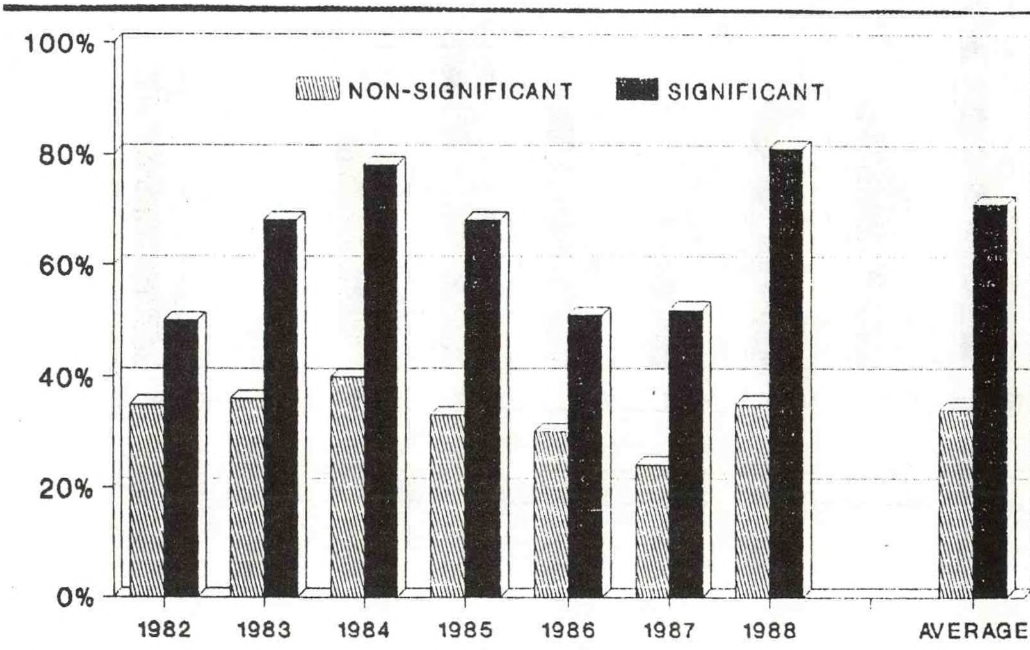


Figure 3 POD of killer and non-killer tornados in tornado watches, 1982-1988.



39.4 % for all tornadoes

Figure 4 POD of significant and non-significant tornadoes in tornado watches, 1982-1988

Not only do a large majority of significant and killer tornados occur in tornado watches, but the time the watch was in effect prior to their touchdown is considerable. Figure 5 depicts the effective lead time (the time between when a tornado watch became valid and the time a killer tornado occurred) distribution. Almost two thirds of all forecasted killer tornados occurred two or more hours after a tornado watch was in effect with over 30% occurring after four hours. This figure suggests that prior to a killer tornado, there is a very good chance the threat was communicated to all concerned well in advance. Though not shown, the lead time distribution for significant tornados in watches was similar.

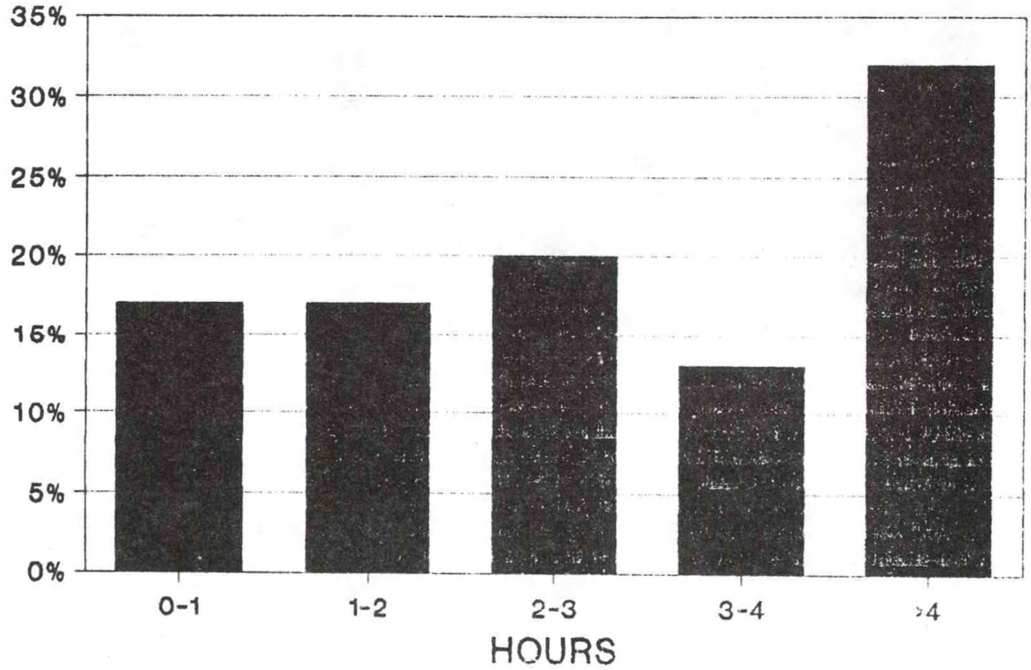


Figure 5 Lead time distribution in hours of tornado watch beginning to killer tornado occurrence, 1982-1988.

3. IMPORTANCE OF TORNADO WATCHES PRECEDING WARNED TORNADOS

To evaluate the role the tornado watch plays in the tornado warning program each tornado was examined as to whether it was either in or close to a tornado watch. "In or close" is defined as being within 60 minutes of the valid time and/or 22 miles of the watch. This assumes that the watch was close enough in time and space to create the desired response by the users, including the meteorologists with warning responsibility.

As shown in Figure 6, there is about an 80% likelihood that a killer or significant tornado will be in or close to a tornado watch prior to its occurrence.

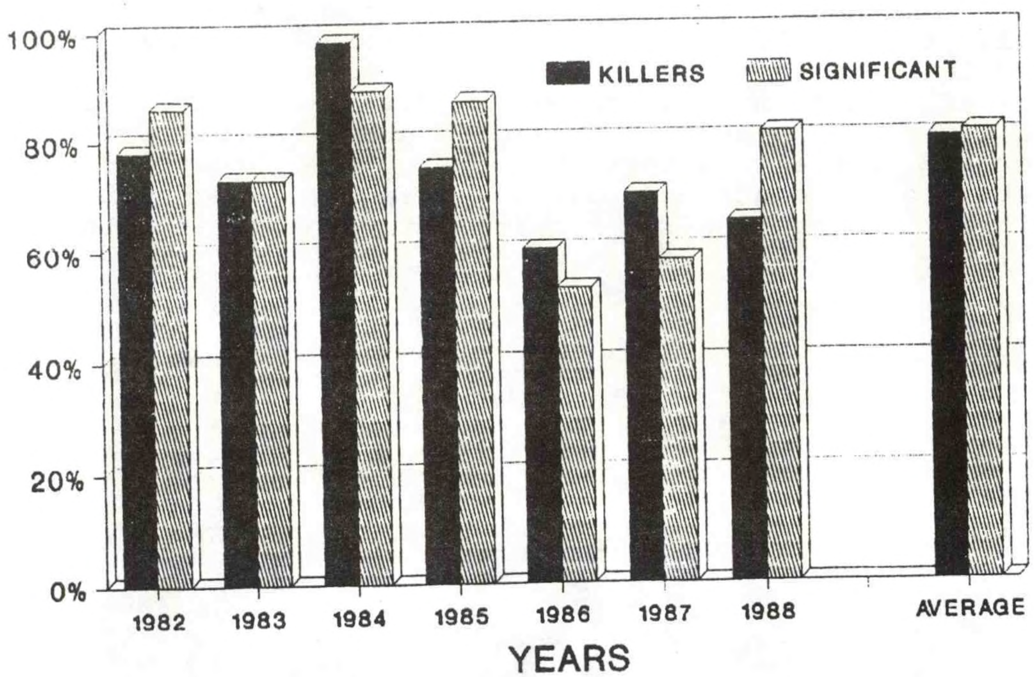


Figure 6 **POD of killers and significant tornados in and close to tornado watches.**

As shown previously, only about 30% of the significant and killer tornados were preceded by tornado warnings. However, examining these important tornados to see how the warning program performed when a tornado watch was in effect versus the times when no watch had been issued provided some revealing results. With killer tornados (Figure 7), there was about a four times better chance of a tornado warning being issued prior to tornado touchdown if a tornado watch was in effect in the vicinity beforehand. Only 10% of the killers were preceded by a warning if there was no tornado watch in effect. With significant tornados (Figure 8), there is double the likelihood that a tornado warning was issued if a tornado watch was in effect.

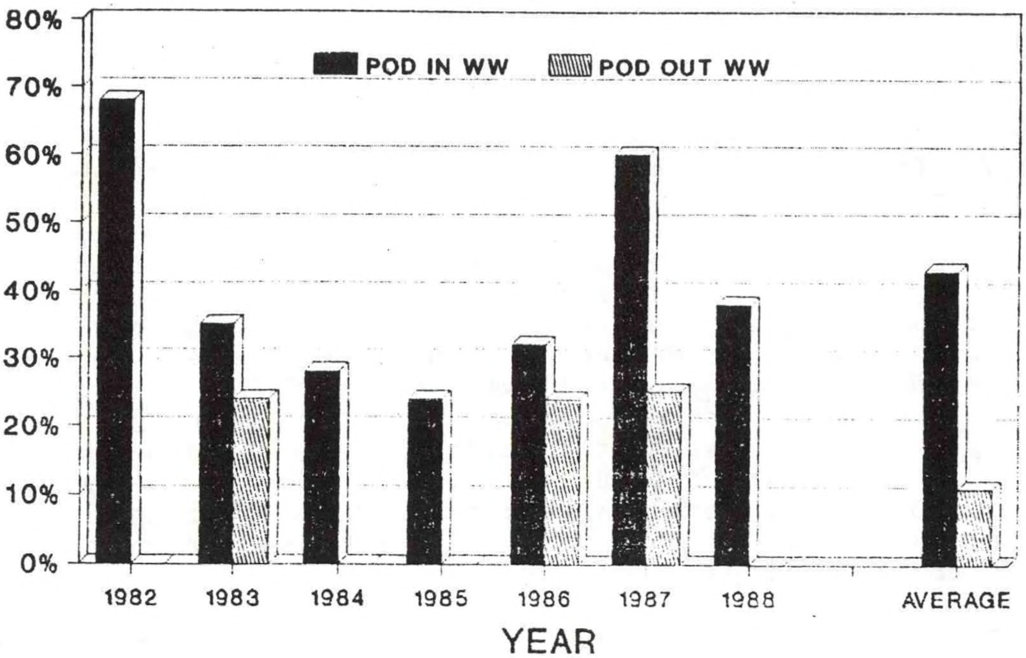


Figure 7 POD of killer tornados in tornado warnings (dependent on the presence or absence of a tornado watch).

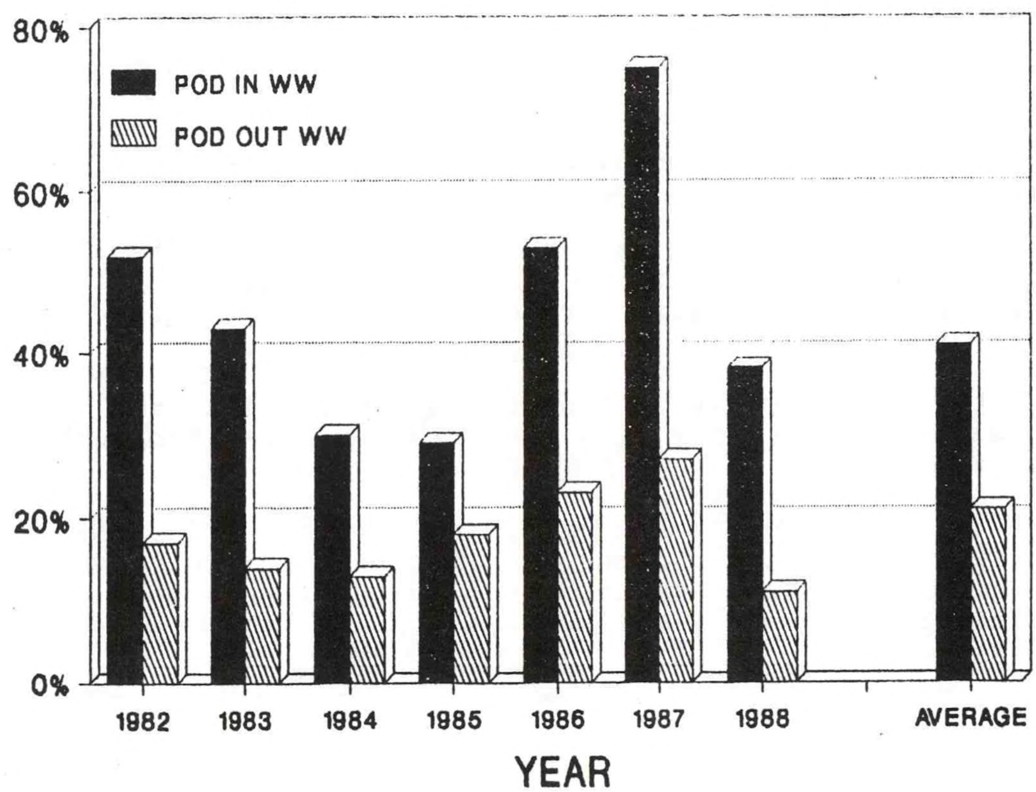


Figure 8 POD of significant tornados in tornado warnings (dependent on the presence of absence or a tornado watch).

Of the 121 killer tornados that were recorded in the period 1982-1988 only four were preceded by tornado warnings that were not first in tornado watches.

Taking the examination one step further, we can subdivide the tornados into a catastrophic category which includes any tornado of F4 or greater intensity and any tornado that results in four or more fatalities. In the seven-year period of study there were 61 of these tornados. Of these 61, 84% were in or close to tornado watches while the POD of these tornados in tornado warnings was only 31%. Again, this shows that tornado warnings have virtually no skill in discriminating between any tornado and the most violent tornado. The POD of disastrous tornados in tornado warnings that were preceded by tornado watches was still just 35%, or only slightly better than for all tornados.

However, the most striking and meaningful statistic as to the importance of having a tornado watch in effect prior to tornado occurrence was that over the seven year period, only one of the 61 disastrous tornados was preceded by a warning when a tornado watch was not in effect.

4. SUPPORT ROLE OF THE TORNADO WATCH IN THE WARNING PROGRAM

The local NWS office that has tornado warning responsibility is handicapped in issuing a warning prior to a significant tornado due to a number of factors:

1. A significant tornado is a rare event. An individual forecaster even in a tornado prone area will possibly have the opportunity to warn on such an event only once every few years.

2. Routine duties could prevent the meteorologist from developing the proper mind-set to be prepared for such an occurrence.

3. The current radar technology (many warning offices have to rely on dedicated drops on remote radars) is very limited in its ability to detect most of the significant tornados.

4. Prior lack of success (high FAR) in verifying warnings biases judgment.

The tornado watch plays a crucial role in the success of the tornado warning program. It counters all the previously listed handicaps in tornado warning issuance.

1. The watch relieves the local forecaster from the need to anticipate a rare event. This is accomplished by the SELS forecaster who routinely handles numerous tornado situations annually.

2. The SELS forecaster's undivided attention is focused on forecasting severe local storms including tornados. Distractions are minimal and the luxury of time to devote to this single forecast problem is available.

3. A tornado watch, by its presence elevates the level of attention given by the radar operators to any radar signature that suggests a possible tornado.

4. Having a watch in effect provides reinforcement to the decision by alerting meteorologists to issue a warning without regard to any high FAR's of the past.

5. CONCLUSIONS

From the results of this study, it can be stated with a high degree of confidence that for a tornado warning to be issued prior to a significant or killer tornado, it is much more likely to happen if a tornado watch is in effect.

This not only is important now but will be in the future as well, even with the new technology such as NEXRAD and Profilers. At Norman, Oklahoma where Doppler technology has been used in the warning program for several years there is still a problem in determining which of the mesocyclone signatures (MCS) is going to produce a tornado. Through personal correspondence with meteorologists at Norman, it has been found about 20% of the MCS detected actually result in tornado warnings being issued. They also stated that the two most important factors used to determine whether a warning will be issued by WSFO Norman on any MCS are (1) whether it is in a tornado watch and (2) whether a tornado has been observed.

Only within limited ranges will both the MCS and tornado vortex signatures (TVS) be detected by NEXRAD Doppler (Chrisman, 1988). TVS will be detectable operationally 60 km from the radar site which will cover only about 23 percent of the NEXRAD 200 km umbrella of responsibility. The MCS will be limited to 120 km from the radar site and will cover only about 50 percent of the area each radar is expected to cover.

Not only does this study bring out the importance of the watch product in the warning program, it also points out the importance of understanding the specialized meteorology associated with significant tornado occurrences. The watch product is the end result of the meteorological interpretation of the situation. This same meteorological input needs to be there in the warning program as well, to enable the meteorologist issuing warnings to act on signatures from the new technology rather than react to the tornado sightings as the current system does for the most part.

To take maximum advantage of the new technology that will be available in the coming decade to provide improved warnings, it is imperative that: 1) a high quality watch program be continued and improved and, 2) that meteorology play a much greater role than it currently does in the warning program.

6. ACKNOWLEDGEMENTS

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