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

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Abstract

The tornado warning is one of the single most important severe weather products that the National Weather Service issues. Considerable effort is made to provide the information needed to issue a tornado warning in an accurate and timely manner. The tornado watch is a crucial ingredient in this support.

The objectives of this paper are to evaluate the service provided by the Watch/Warning program during significant tornado occurrences and to point out the important role tornado watches play in support of the tornado warning program.

This study used tornados that resulted in fatalities, plus those rated F3 or greater on the Fujita scale, from the period 1982–1988. For this paper only, the term significant will be used to describe these tornados. Each of these tornados were checked to determine their inclusion 1) in or close to a tornado watch and 2) in a tornado warning.

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

Significant tornados were preceded by tornado warnings in about 30% of the cases studied. However, of these warned tornados, over 90% were preceded by tornado watches. This confirms the critical nature of the tornado watch in setting the stage for timely warnings. This is accomplished by creating a proper mind set in the field forecaster by stressing the meteorological parameters driving the tornado threat. Also, the watch can serve to activate spotter networks, which provide important feedback to the warning meteorologist and possibly increase tornado sightings. The findings of this study suggest that for the optimum public service it is critical that a tornado watch be in place prior to the occurrence of a significant tornado.

1. Introduction

One of the most important life saving public products 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.

It is well known that the most intense tornados are the result of strong meteorological forcing in the atmosphere. However, these only make up a small fraction of the annual tornado occurrence. A large majority of tornados are of a weaker variety and are very difficult to detect by current radars. These weaker tornados complicate the evaluation of skill in the forecasting and warning system. To properly evaluate the NWS tornado watch and warning program, the emphasis needs to be on the type of watch and warnings that were in effect when the more significant tornados occurred (as suggested by Hales, 1987).

The objective of this paper are two fold: 1) to evaluate the effectiveness of tornado warnings during the occurrence of the most damaging tornados and 2) to illustrate the importance of having a tornado watch in place prior to the tornado touchdown.

2. Methodology

Tornados are divided into three categories (realizing the subjectivity inherent in tornado intensity classification): (1) those that result in loss of life, (2) those that have the highest potential of causing loss of life and considerable damage (F3 and greater) and (3) all tornados together. Emphasis will be placed on the first two categories, which for clarity in this paper will be called "significant tornados" (not to be confused with the definition of significant used by Hales (1987)). Routine verification (including past summaries of verification results) has treated watch (Leftwich, 1988) and warning (Grenier et al., 1988) verification separately. This papers intent is to look at them together and the importance of watches preceding warnings.

The period of study for this paper will be from 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 killer tornados. It is readily seen that the significant tornados make up only a small percentage of the annual total. There is some variation in tornado occurrence from year to year but the annual range in the significant events is much greater. For example, 1982 and 1984 had 300% more significant tornados than each of the years 1985–1988. All tornados in 1982 and 1984 numbered only about 30% more than 1985–1988.

For purposes of this study, a tornado occurrence is defined as a documented tornado in a single county. For example: if a tornado track includes three counties, it is counted as a

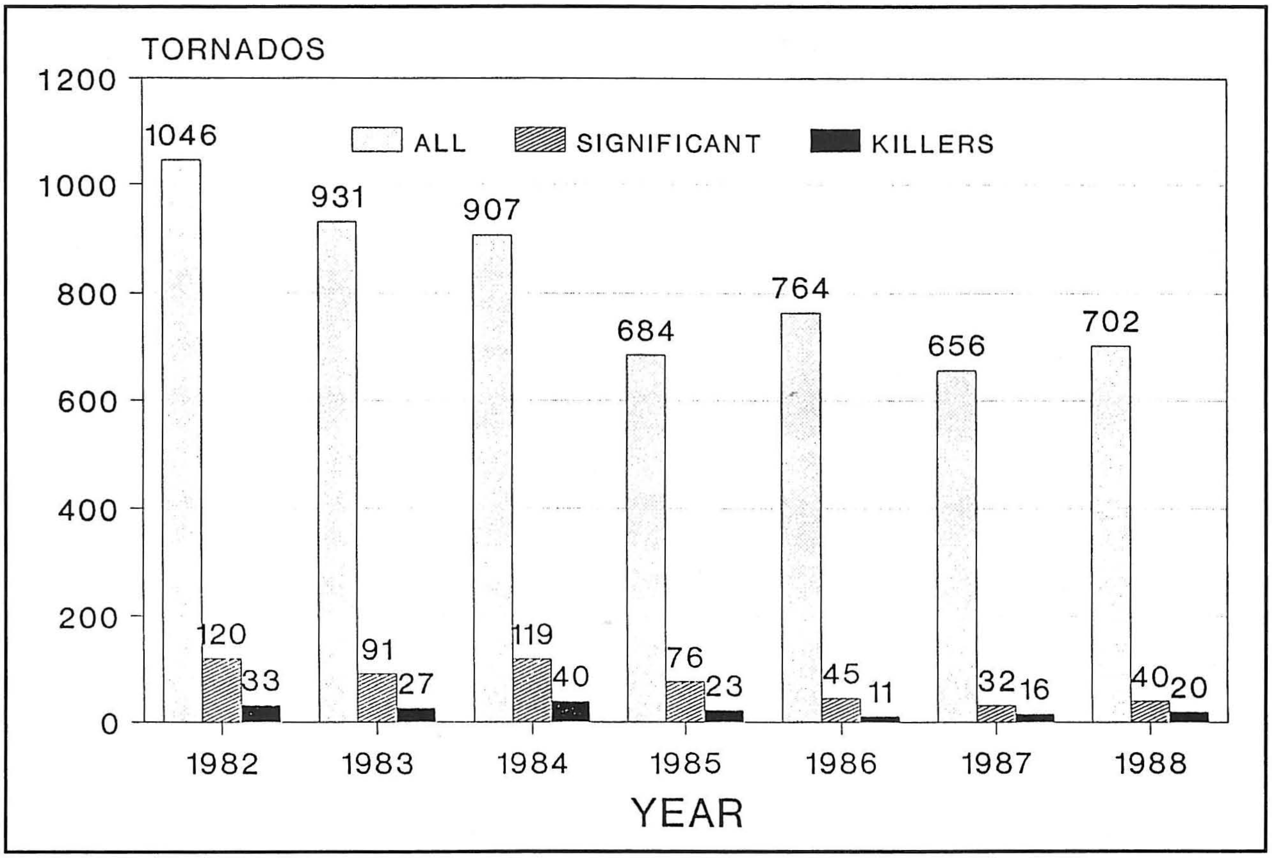

Fig. 1. Annual tornados, all, significant and killers, 1982–1988.

separate tornado occurrence 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. Likewise, a killer tornado that results in fatalities in more than one county will be counted as a separate killer tornado for each county in which a fatality occurred.

3. Tornado warnings and watches

An examination of the probability of detection (POD) scores (Fig. 2) of tornados with tornado warnings shows there is little skill difference in warning for significant tornados versus all tornados. This may be because many tornado warnings are based on sightings. Regardless of the tornado intensity, there is only about a 30% chance that it will be preceded by a tornado warning.

There is considerable increase in skill in issuing watches for significant tornados. Figure 3 shows that a killer tornado is almost twice as likely to be included in a tornado watch as a non-killer tornado. Skill in posting watches for significant tornados (Fig. 4) is even a little better than that of the killer tornados. Figure 4 shows an average of 71% of all significant tornados occurring in tornado watches versus 35% of all other tornados. Although the number of severe thunderstorm watches issued annually exceeds tornado watches, only about 5 percent of the significant tornados occurred in severe thunderstorm watches. This indicates considerable skill in 1) discriminating between tornadic and non-tornadic severe weather threats and 2) forecasting for the more intense tornados.

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 forecast 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 there is a very good chance the threat of a killer tornado was communicated well in advance. Though not shown, the lead time distribution for significant tornados in watches was similar.

4. Importance of tornado watches preceding warned tornados

It is conjectured that the issuance of a tornado watch increased awareness both in, and for some distance around the watch area. To evaluate the role tornado watches play in the warning program, it was determined if each tornado occurrence was in or close to a tornado watch. "In or close" is defined as being within 60 minutes of the expiration time and/or 22 miles of the watch area.

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

As shown previously, only about 30% of the significant and

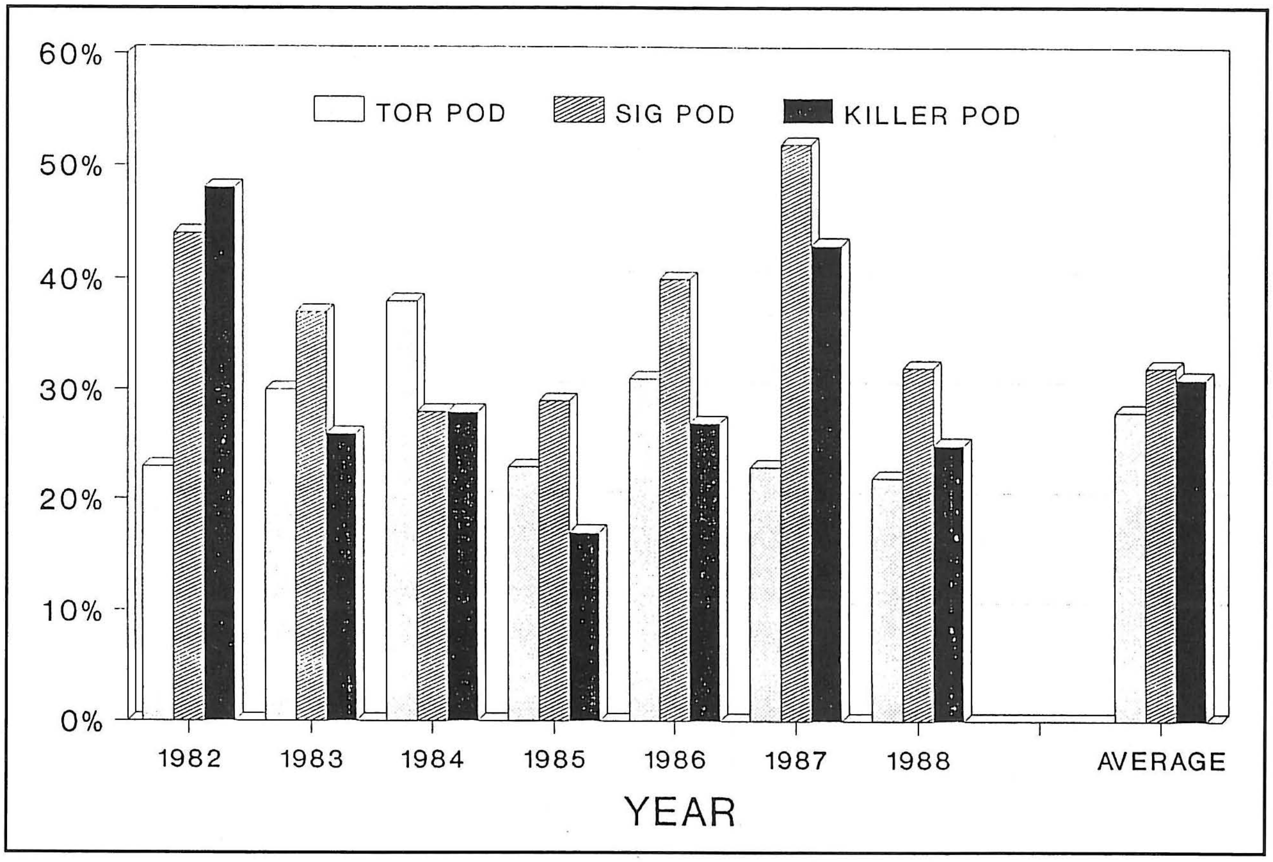

Fig. 2. POD of tornados in tornado warnings, all, significant and killers, 1982–1988.

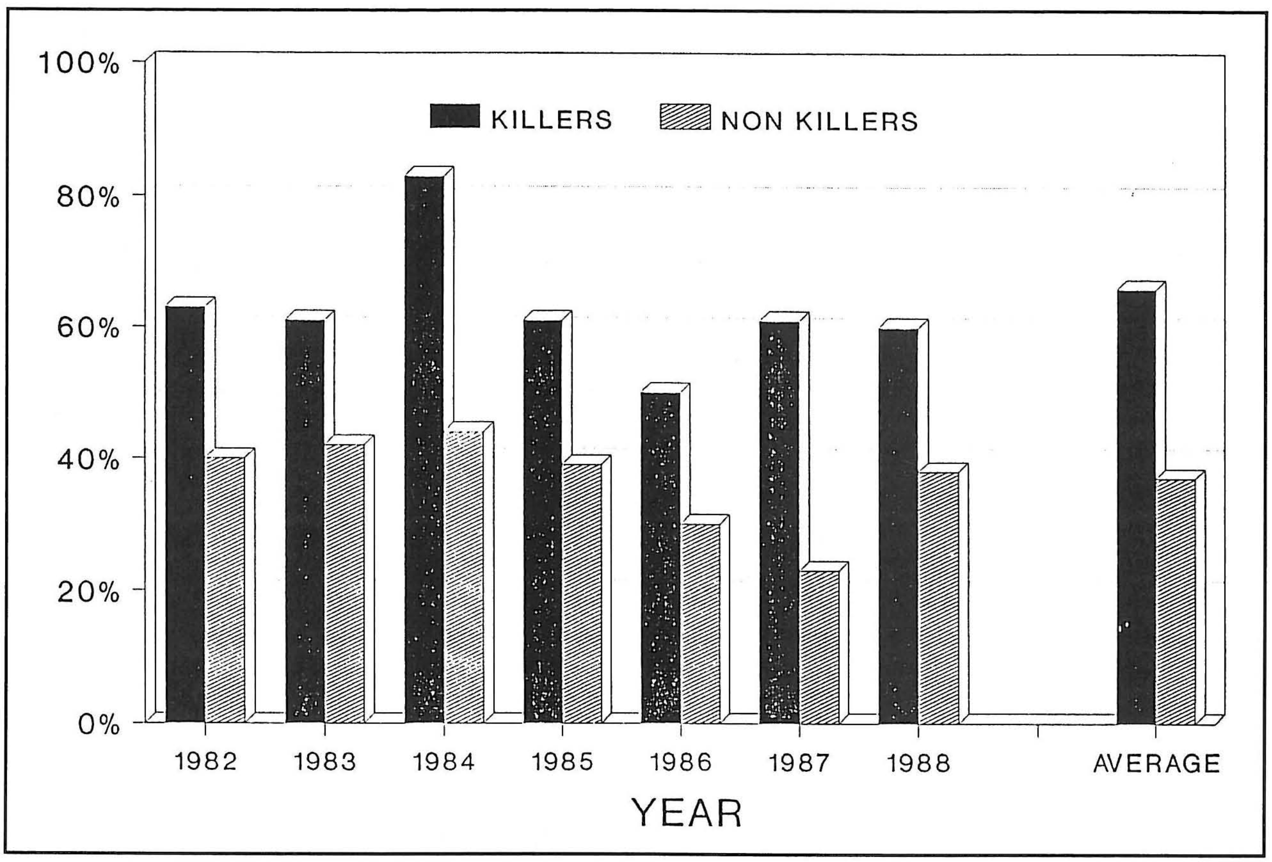

Fig. 3. POD of killer and non-killer tornados in tornado watches, 1982–1988.

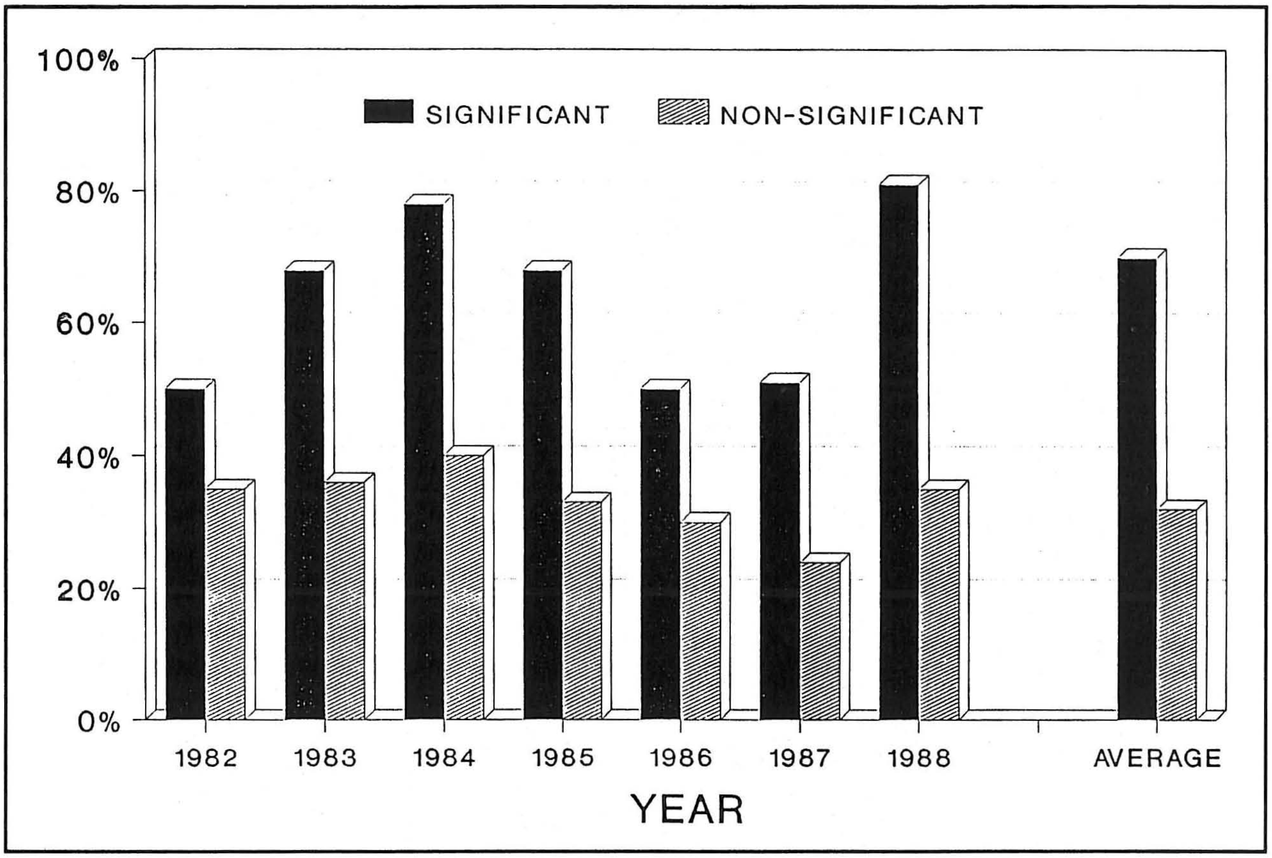

Fig. 4. POD of significant and non-significant tornadoes in tornado watches, 1982–1988.

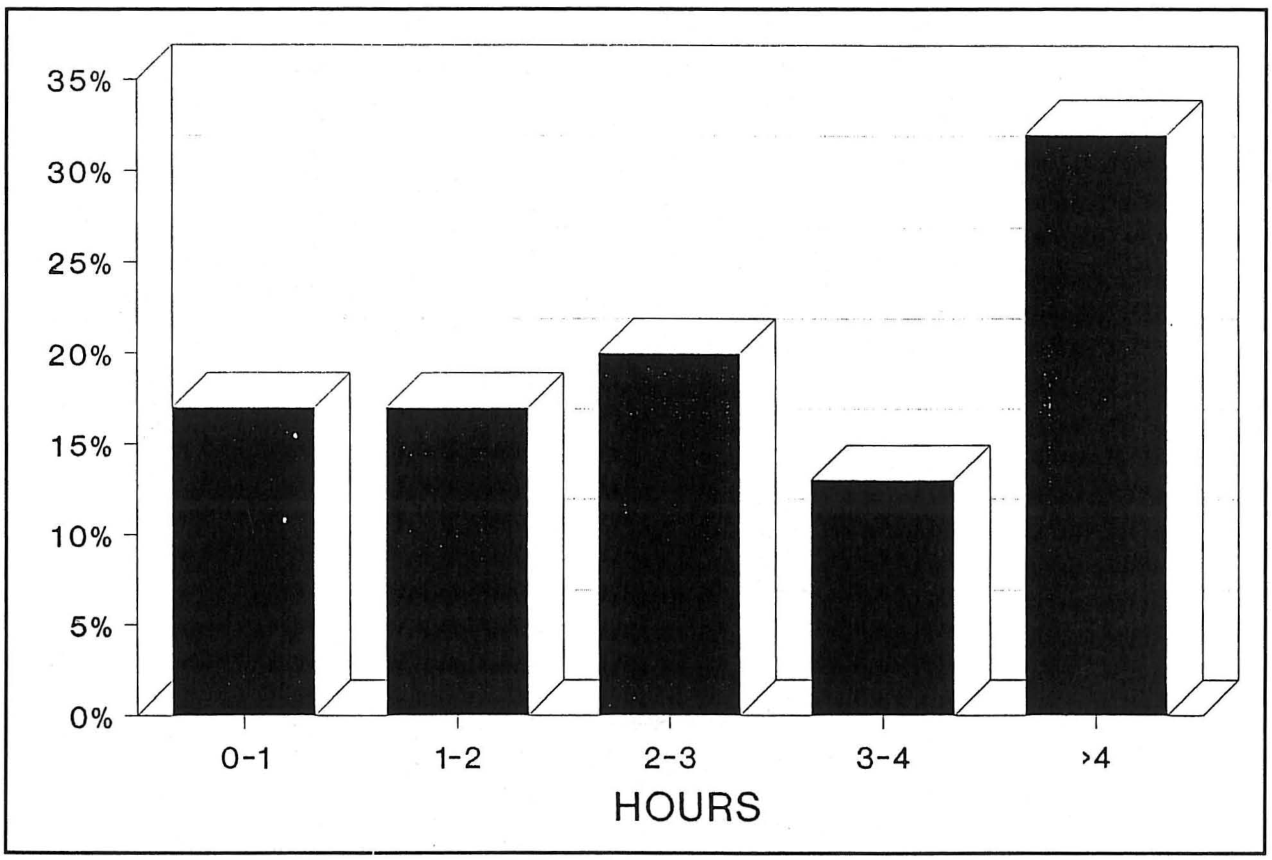

Fig. 5. Lead time distribution in hours of tornado watch beginning to killer tornado occurrence, 1982–1987.

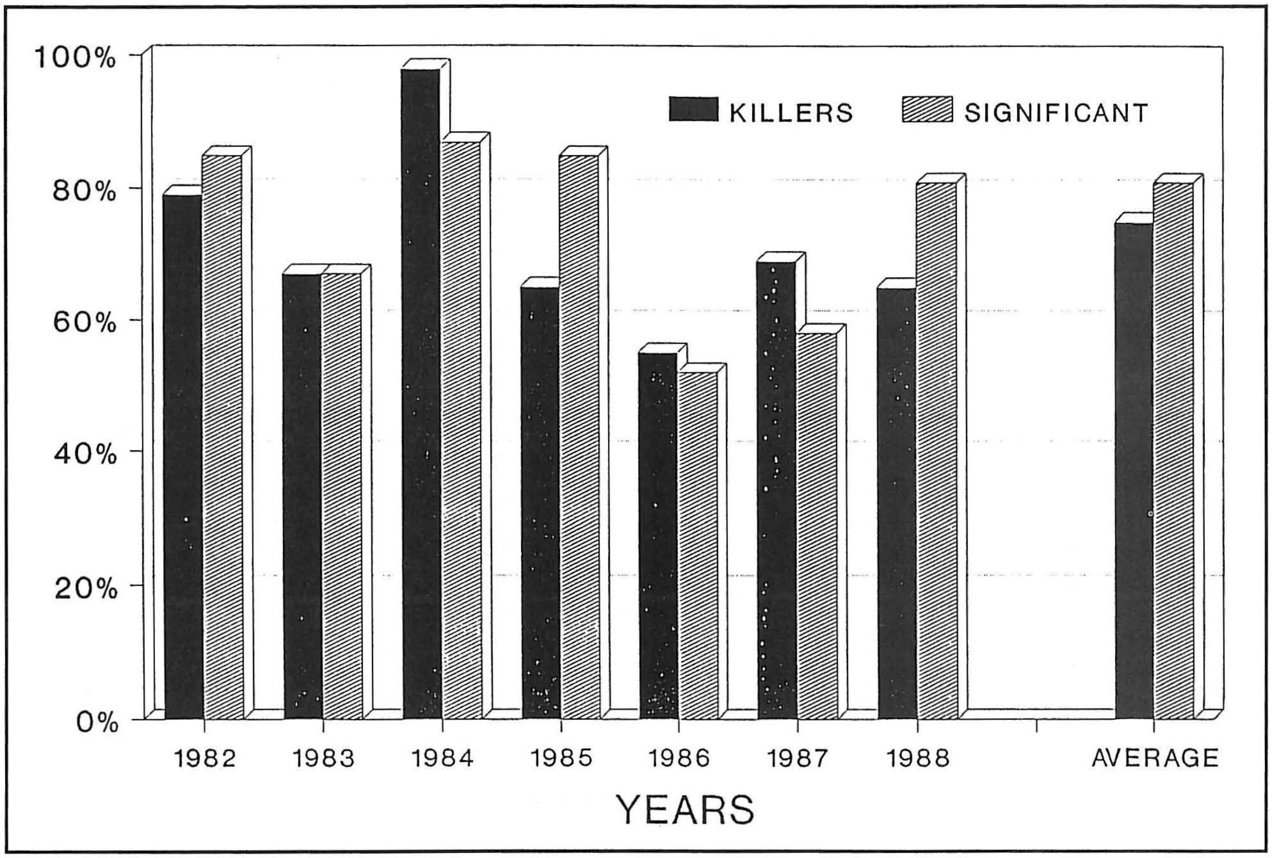

Fig. 6. POD of killers and significant tornados in and close to tornado watches.

killer tornados were preceded by tornado warnings. Further, examining warning performance for killer tornados with and without tornado watches in effect provides some interesting results. With killer tornados (Fig. 7), tornado warnings were 4 times more likely to be 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 no tornado watch was in effect. With significant tornados (Fig. 8), a tornado warning is twice as likely if a tornado watch was in effect.

It is important to note at this point that a watch and a warning are two entirely different products with distinct roles. The purpose of a watch is to identify an area that has potential for tornado development in a specified time frame; while a warning is a response to cues that a tornado is or is very likely to be occurring. It is acknowledged that there are multi-variable factors involved in the watch/warning process and that the conclusions drawn from this data may be more of a correlation than a cause and effect. The purpose in this paper is not to make a direct comparison of watch verification to warning verification.

Of the 170 killer tornados that were recorded in the period 1982–1988, only five were preceded by tornado warnings that were not first in or near tornado watches.

5. Support role of the tornado watch in the warning program

The local NWS office with 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, may only have the opportunity to warn on such an event 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. Current radar technology (many warning offices have to rely on dedicated drops on remote radar) is very limited in its ability to detect most significant tornados.
4. Prior lack of success (high false alarm rate (FAR)) in verifying warnings biases judgement.

The tornado watch can play a critical role. In countering all of the previously listed obstacles to tornado warning issuance:

1. The watch can aid the local forecaster in developing the mind-set needed to anticipate a rare event. The watch is issued by the Severe Local Storms (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 radar operators to any radar signature that suggests a possible tornado. Spotters will likely have a heightened awareness of tornado potential with any observed thunderstorm.

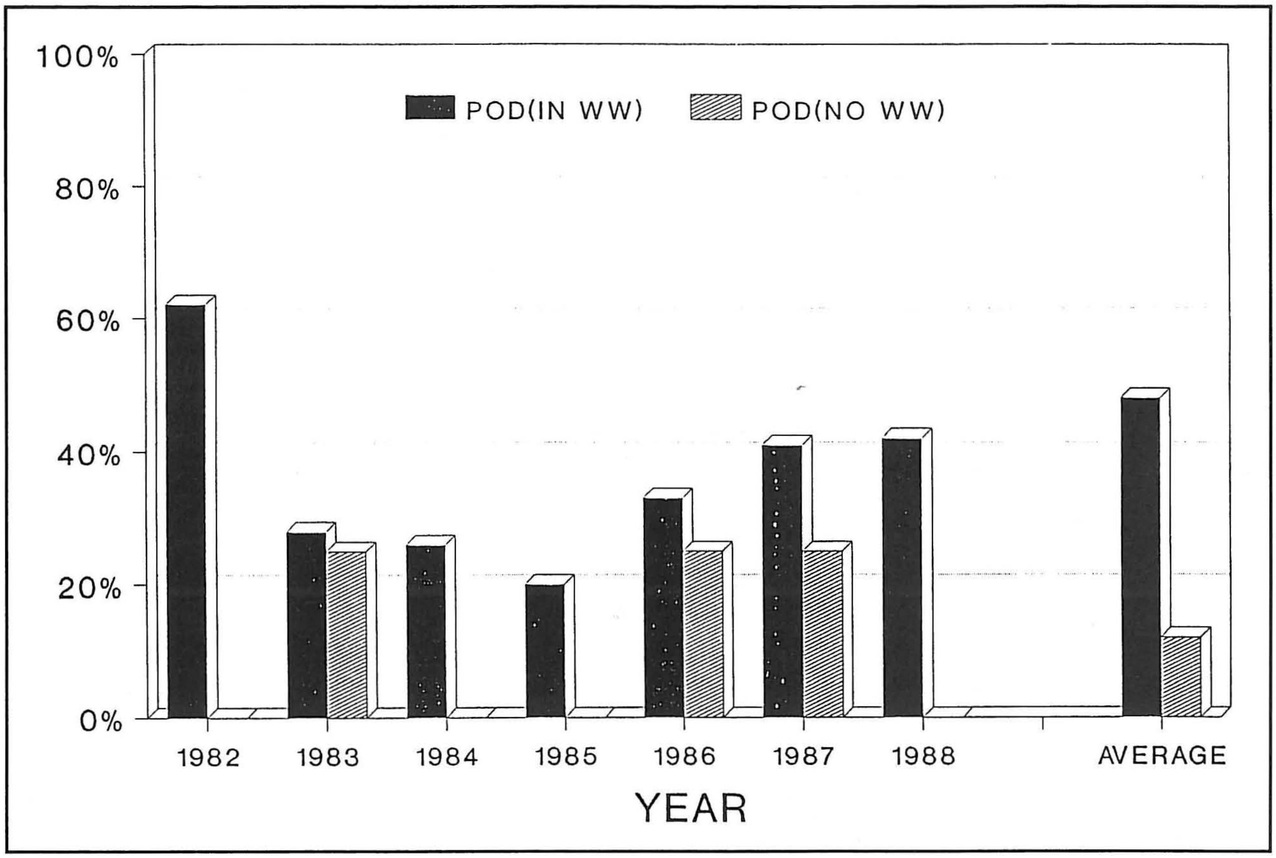

Fig. 7. POD of killer tornados in tornado warnings (dependent on the presence or absence of a tornado watch).

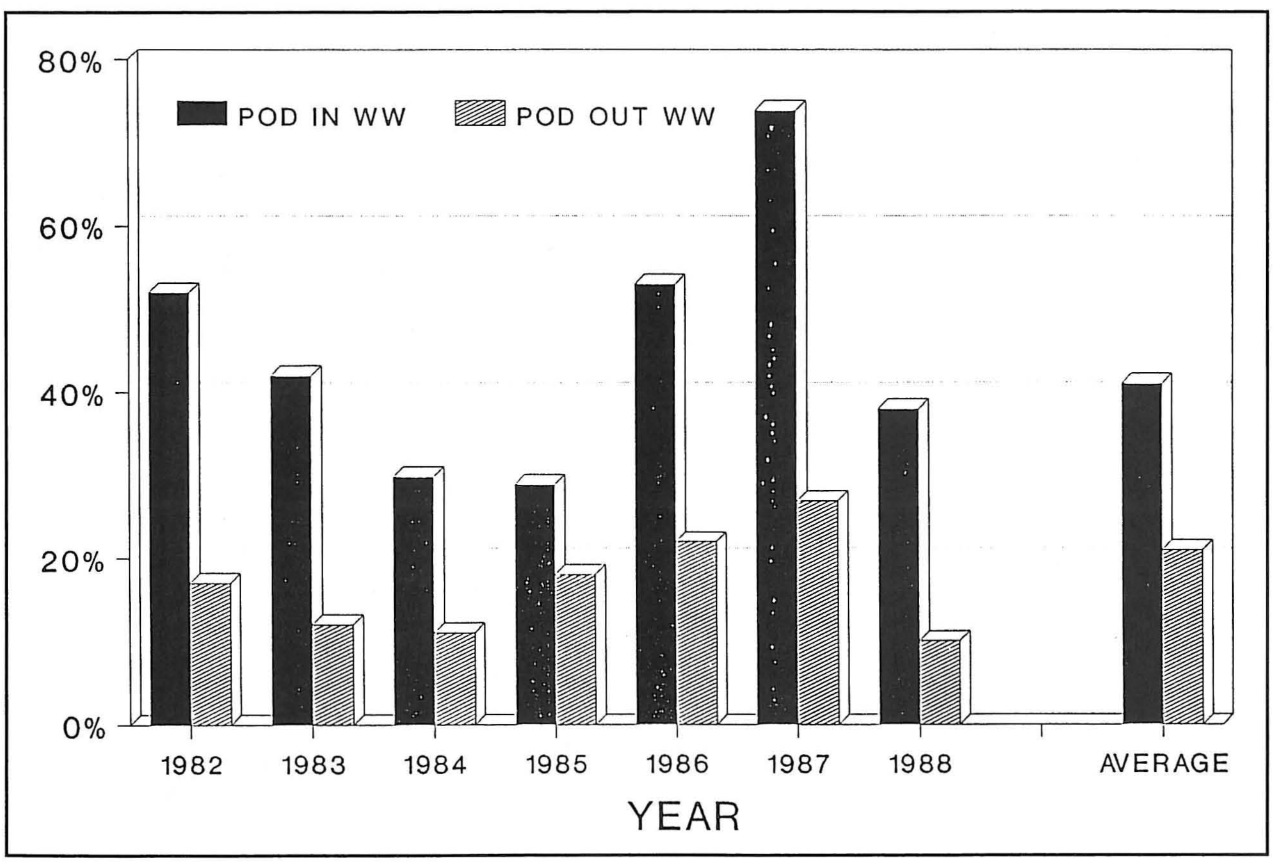

Fig. 8. POD of significant tornados in tornado warnings (dependent on the presence or absence of a tornado watch).

Having a watch in effect reinforces the warning decision. Meteorologists may be more likely to issue a warning without regard to bias from high FAR's of the past.

6. Conclusions

The results of this study indicates that tornado warnings for significant tornados are more likely to be issued if preceded by a tornado watch.

Not only does this study highlight 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. The same meteorological input is essential in issuing warnings, enabling the warning meteorologist to more often act on cues from new technology (particularly WSR-88D), rather than reacting almost exclusively to sightings.

To take maximum advantage of the new radar capabilities in the next decade and improve warnings, it is imperative that: 1) a high quality watch program be continued and improved and, 2) meteorology play a much greater role in the warning program. This can be best accomplished through improved training in meso-scale meteorology and storm structure.

Author

John E. Hales, Jr. has been a Lead Severe Storms Forecaster at NSSFC in Kansas City since 1975. He previously worked at NWS offices as an observer in Seattle during 1967–1969, and as a forecaster in Phoenix during 1969–1975. He received his Meteorology education from the University of Utah, earning the B.S. degree in 1965 and the M.S. degree in 1967.

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