NOAA TECHNICAL MEMORANDUM NWS NSSFC-15

AN EXAMINATION OF THE NATIONAL WEATHER SERVICE SEVERE LOCAL STORM WARNING PROGRAM AND PROPOSED IMPROVEMENTS

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January 1987

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

NOAA TECHNICAL MEMORANDA

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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AN EXAMINATION OF THE NATIONAL WEATHER SERVICE SEVERE LOCAL STORM WARNING PROGRAM AND PROPOSED IMPROVEMENTS.

JOHN E. HALES JR.
NSSFC

ABSTRACT

The National Weather Service uses verification algorithms to evaluate the quality of its severe local storm watch and warning service. With the increased emphasis in recent years on verification many weather service offices have taken steps to better their statistics. Some have developed improved warning techniques, others have developed post-storm survey procedures. Problems that can result, such as an unrepresentative severe local storm climatology and misleading verification statistics are discussed.

Stratification of severe local storm events by intensity prior to using these data in verification of watches/warnings provides a more realistic measure of the effectiveness of the warning service. Examples of resulting statistics and possible applications are presented.

1. INTRODUCTION

The National Severe Storms Forecast Center has been verifying tornado and severe thunderstorm watches for accountability purposes for much of its existence. The generalized verification algorithm was applied to the severe local storm warning program in 1979 (Pearson and David, 1979). The emphasis of the verification system has been on the validation of the forecast products, and does not incorporate the degree of severity of the report that resulted in the product validation, nor does it reflect the detectability of the event.

Reported tornadoes which showed a steady increase for several years (Fig. 1) after the establishment of NSSFC in the early 1950's leveled off by the mid 1970's such that the annual fluctuation is now more a function of the weather than the reporting system. On the other hand reports of damaging winds and large hail showed an increase thru the 1970's. With the commencement of warning verification the number of severe reports has doubled. Until the 1970's there was not a great deal of effort to maintain a comprehensive record of the severe thunderstorm reports (wind gusts in excess of 50 kt, 3/4 inch hail or greater and wind damage).

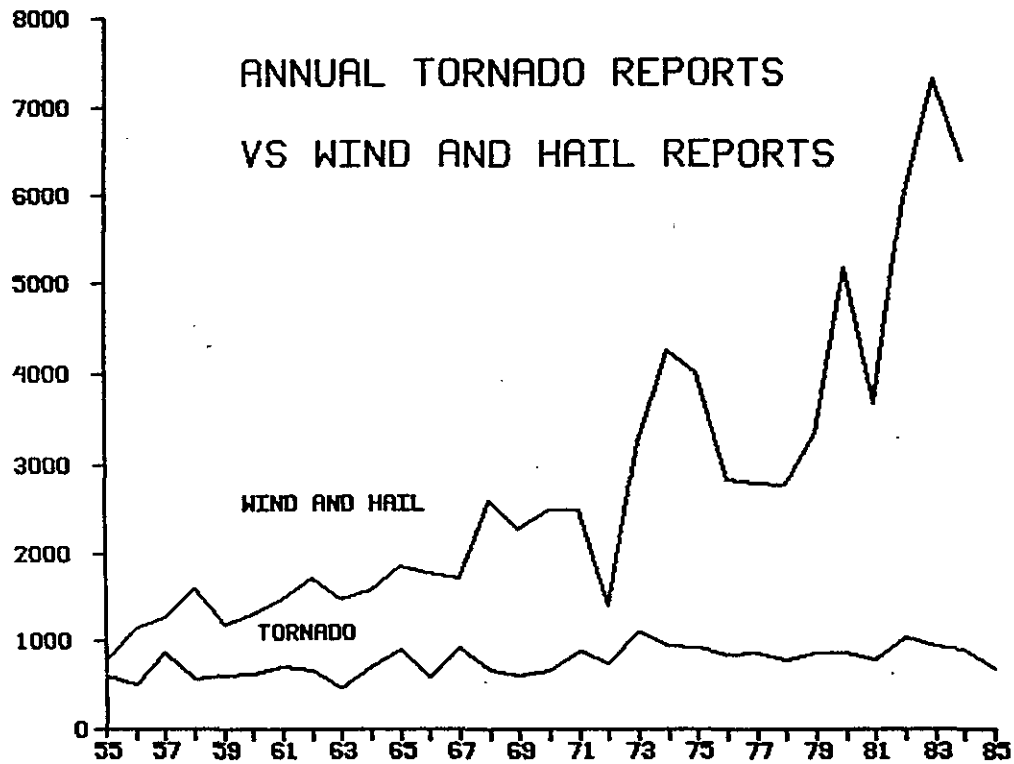


Figure 1. Annual tornado and wind and hail reports in the United States from 1955-1983.

However, with the commencement of the verification program all of this changed. It appears that many warning offices soon realized that to improve their verification scores they would have to take one of several courses of action. They could decrease the number of warnings being issued; by using more restrictive warning criteria; or subjectively pre-determine the chances of receiving a severe report prior to making the decision to issue a warning; or they could develop new post-storm procedures for finding severe reports. They could also improve their radar warning criteria through training and applying new techniques. Analysis of the warning and severe report data suggest that one or more of these approaches has been incorporated at many of the stations.

The National Weather Services Operation Manual states that "the National Weather Service has no greater statutory responsibility than preparing and distributing forecasts and warnings of impending severe weather". Since the increasing degree of severity of a storm has a proportionately greater potential impact on life and property it can be argued that a higher level of accountability would be desirable.

Since the event data base presently treats all reports equally, there is no way to evaluate watches and warnings as they relate to the severity of an event and its impact in human terms. Incorporating this type of information would also be of considerable value to a meteorologist in developing his own experience levels.

The distorted severe event distribution will be examined in some detail relating it to the advent of warning verification. Also a new verification term called PODS (Probability of Detecting a Significant event) is proposed that will facilitate a better evaluation of the effectiveness of the severe local storm forecast and warning system. For this statistic, only the most severe events will be included, This new statistic, used in concert with the existing verification output, can provide positive reinforcement to the meteorologist in carrying out his responsibility of alerting the public to the threat of severe weather.

2. WARNING VERIFICATION SYSTEM

The present verification system by the National Weather Service (National Weather Service, 1982) emphasizes evaluation of the warnings. The two elements necessary for verification are: (1) issued warnings, and (2) event reports.

To qualify as a severe local storm "event", a report must satisfy one of the following criteria (National Weather Service, 1982):

(1) Tornado - a funnel or rotating circulation touching the ground,

(2) Hail equal or greater than 3/4 inch in diameter,

(3) Convective wind gust of at least 50 knots, and

(4) Significant convective wind damage.

Multiple reports of the same type occurring within 10 statute miles and 15 minutes of each other and in the same county are recorded as one event with the exception of tornadoes. Any event that occurs both within a county for which a warning has been issued and at a valid time is a "warned event". Thus, one warning can cover many events. The Probability of Detection (POD), which is a measure of the correctness of the warnings in time and space, is computed as follows:

POD = warned events/total events.

In current verification procedures (Leftwich and Lee, 1984), the county is the basic unit of area. A warning that covers three counties is counted as three "warned counties." At least one severe event occurring during the valid period of a warning in a warned county produces a "verified county". In order to obtain complete verification of a warning, at least one severe event must occur in each warned county. From these parameters a False Alarm Ratio (FAR) is computed (as a measure of overwarning) as follows:

FAR= 1 - number of verified counties/number of warned counties.

These two statistics are combined to form another statistic, the Critical Success Index (CSI) as follows:

$$CSI=(POD^{-1}+(1-FAR)^{-1}-1)^{-1}$$

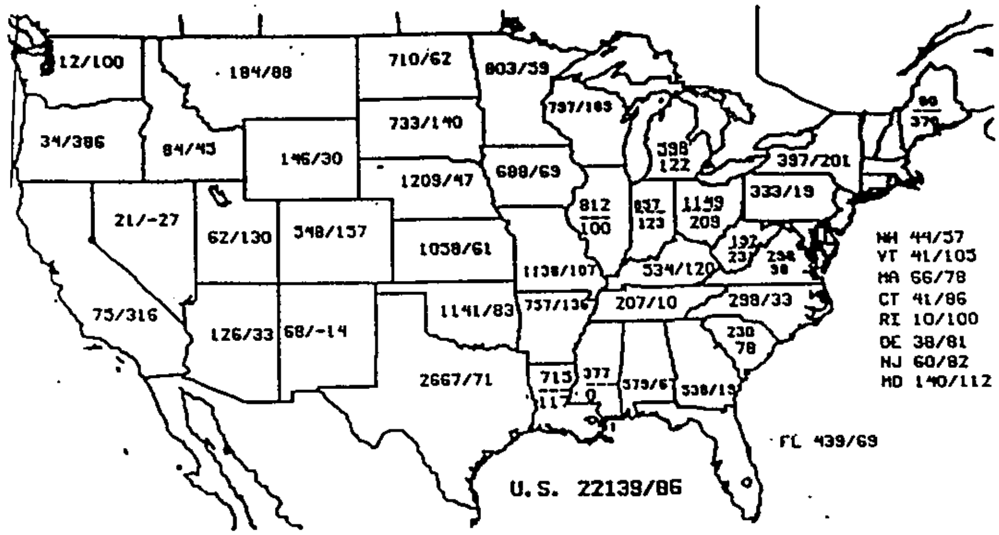
The maximum value is 1 and the minimum value is 0, a higher score representing a better verification. The CSI, which is the same as the Threat Score, is the fraction of the time a severe event was correctly forecast when either the threat event occurred, or was forecast, or both.

A serious weakness in using this type of system to evaluate the effectiveness of the warnings is the unrepresentative nature of the severe event data base. For this system to operate properly and produce meaningful results one must have to assume that the data are not biased. Lemon (1979) suggested that an apparent improvement in warning quality can be made by improving the ground truth data used for verification.

3. INTERDEPENDENCE OF SEVERE EVENTS AND WARNINGS

The NSSFC archives all reports of severe thunderstorms and tornadoes for the United States as well as the individual severe thunderstorm and tornado warnings. Since the verification of warnings began in 1979 two 4 year periods (1976-1979 and 1980-83) were examined. In this paper the period of 1976-79 will be called BV (before verification) and the period 1980-83 AV (after verification began). The year verification began (1979) was included in the BV period as any response to verification would not have occurred until the results of the first year were available. For each period a program was produced to list the number of warnings issued for each county in the country as well as the number of severe thunderstorm reports. The goal is to see just what effect the initiation of the verification had on the data. Since counties are so diverse in both population and size, normalized report statistics for each county were also developed. Listings were generated to show both how may reports per thousand population and per thousand square miles occurred.

A state tabulation of severe thunderstorm reports is shown in Figure 2 for the AV period along with the percentage change from the BV period. Looking at those states east of the Rockies where most of the severe thunderstorms occur there is a wide range of changes.



TOTAL NUMBER OF SEVERE THUNDERSTORM REPORTS 1980-1983

WITH THE PERCENTAGE CHANGE FROM THE PERIOD 1976-1979

Figure 2. Total number of severe thunderstorm reports 1980-1983 in the United States with the percentage change from the period 1976-1979.

Ohio had the largest increase with over 209% while Mississippi had no change. Nationally there was an 86% increase from BV to AV. This is an increase of over 10,000 reports of severe weather! Though not shown for each state there are wide ranges of changes within many of the states. For example in Missouri severe reports were up 107%, much of which could be attributed to the increase in WSO Columbia counties. There were 330% more reports of severe weather in Columbia's area of responsibility with the remainder of Missouri only increasing 62%.

Selected areas were chosen to examine some of the changes to which the initiation of verification could have contributed to.

a. MISSOURI

Missouri has four NWS offices that have warning responsibility. WSFO St. Louis and WSO Kansas City are responsible for both densely populated urban areas as well as low density rural counties. WSO Columbia and WSO Springfield are primarily rural with the exception of their immediate counties.

An examination of the distribution of the severe thunderstorm reports for both periods dramatically illustrates the bias the data has for areas of high population and proximity to a NWS warning office. This bias is much greater than that found by Kelly and Schaefer (1982). Of even more interest is the very dramatic change that occurred in the counties under WSO Columbia's warning responsibility. In the BV period the number of severe reports in the densely populated counties (Fig. 3) around Kansas City and St. Louis was one to two orders of magnitude greater than some of the nearby rural counties (some counties reported no severe weather for the 4-year period).

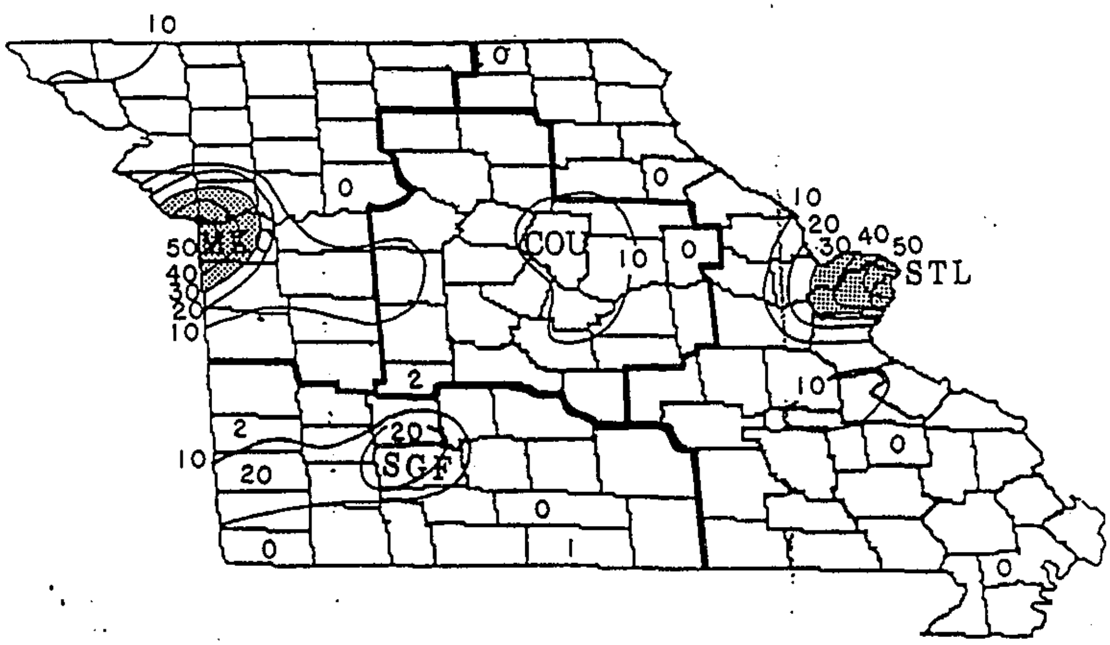


Figure 3. Analysis of Missouri severe thunderstorm reports per 1000 sq. mi. from 1976-1979. Heavy outline is the area of county warning responsibility for the station indicated.

There is also evidence of a maximum in reports in the county which includes WSO Springfield and to a lesser extent WSO Columbia. The distribution of warnings in the BV period (Fig. 4) also shows a strong bias toward the population centers, as well as the number of warnings issued is inversely related to the distance from the warning site.

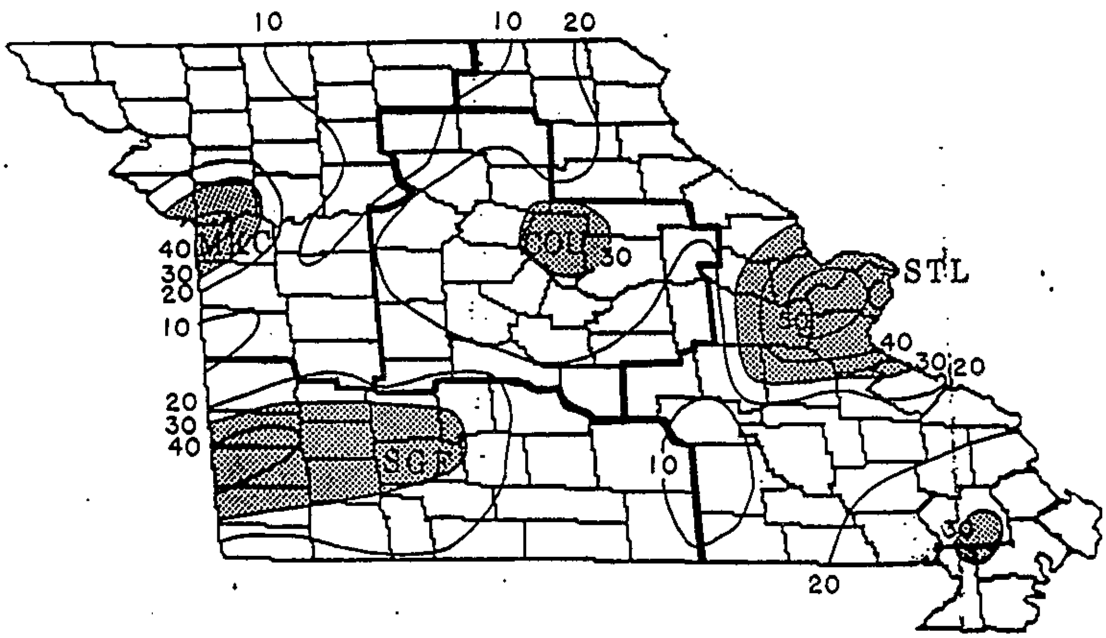


Figure 4. Analysis of all Missouri county severe thunderstorm and tornado warnings for period 1976-1979. Heavy outline is the area of county warning responsibility for the station indicated.

Again this is in considerable disagreement with Kelly and Schaefer (1982) who found little tendency towards warning neighboring communities at the expense of more remote ones. Some of the outlying counties, particularly in northwest Missouri, are warned on severe thunderstorms less than a quarter as frequently as urban counties. The current severe storm climatology supports this variation of warnings, however upon examining the severe event distribution it becomes apparent there is a considerable distortion in the data not related to the meteorology of the area. Certainly the climatology of severe storms cannot support this extreme variation in such short distances. Speculation can be made that the decision to issue the warning takes into account two factors other than the radar signatures: (1) whether a severe report has been received from the storm (which is highly dependent on where the storm is, as has been shown in Fig. 3); and (2) what the likelihood is of receiving a report from the storm in the county to be warned (subjective climatology). (These procedures have been substantiated by some of the meteorologists at the warning sites through personal communication.)

Looking at the data for the AV period shows a dramatic change in both number of reports and warnings issued for the area of WSO Columbia's responsibility. In the BV period Columbia's county of Boone had a barely discernible local maximum of severe reports while the AV (Fig. 5) period has its severe reports surpassing those in both the Kansas City and St. Louis areas which have far greater population.

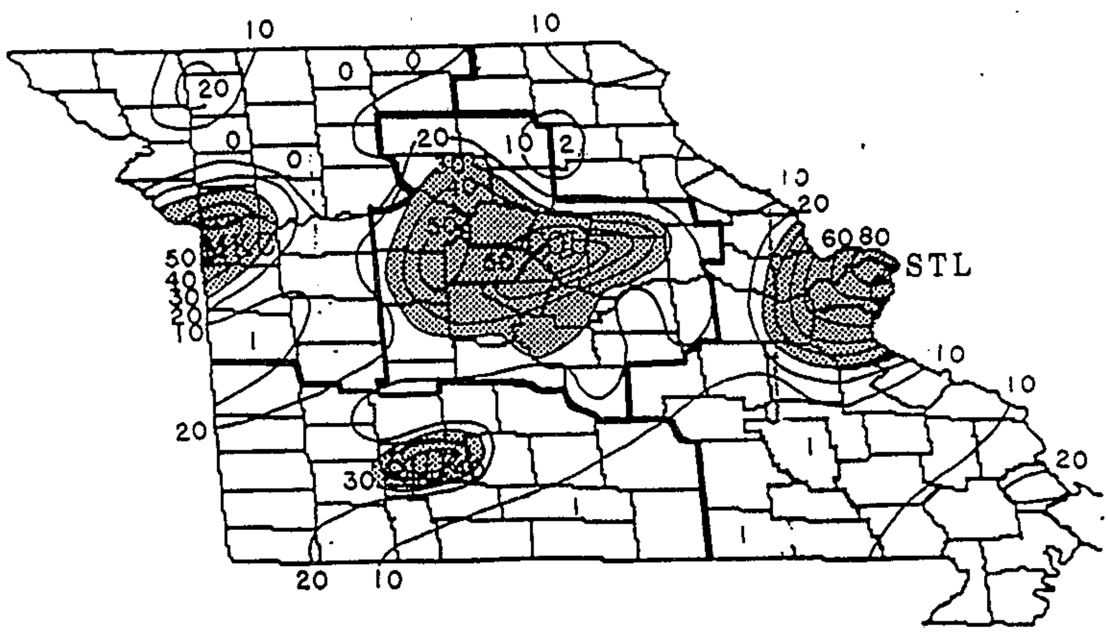


Figure 5. Same as Fig. 2, except for the period 1980-1983.

Unlike the two larger cities where the maximum is a bullseye, there is a much more even distribution of reports throughout Columbia's area of responsibility. The analysis for the AV period (Fig. 6) versus the BV period indicates that fewer warnings were issued in the Kansas City area and about the same in St. Louis's and Springfield's counties.

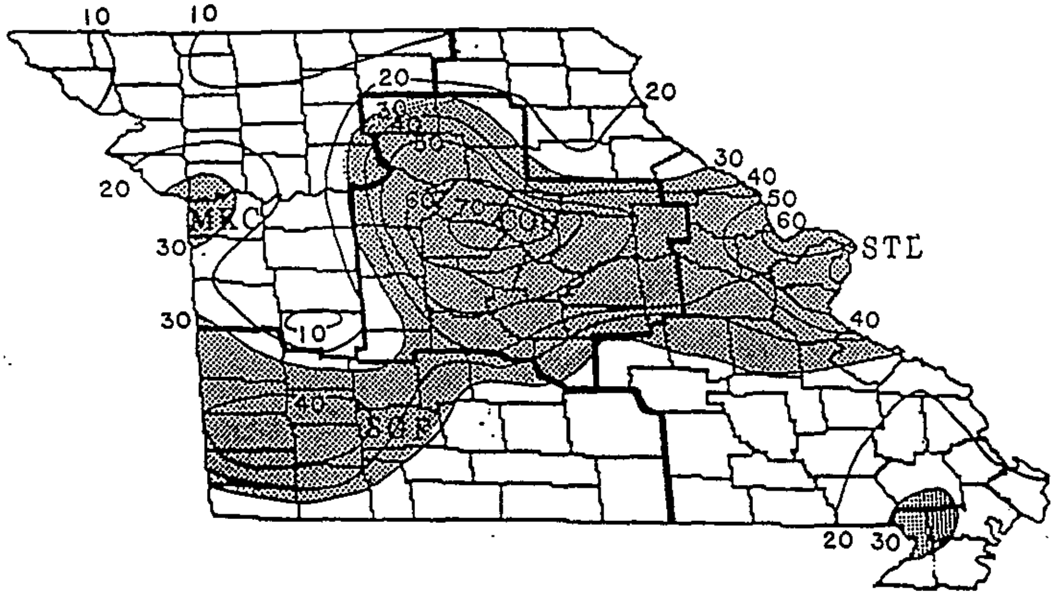


Figure 6. Same as Fig. 3, except for the period 1980-1983.

However, WSO Columbia in concert with the severe reports, greatly increased the number of warnings, more than doubling those in the Kansas City area and far exceeding those in St. Louis. It is suggested that WSO Columbia is now providing an improved service to its area of responsibility as a result of the apparent change in their operational procedures.

With the exception of WSO Columbia's area of responsibility there were no significant changes in both number of warnings and severe reports from the BV to the AV periods in Missouri. Both analyses illustrate the high bias toward the populated areas that are close to warning sites. Columbia, on the other hand, effected a major change as they are now the most active area in the state for both warnings and reports.

There have been some changes at WSO Columbia that partially explain the big increase in number of warnings and reports other than just the initiation of the verification program. In December of 1977, a WSR-74 warning radar was installed. In discussions with the staff, they stated that they were not incorporating the radar extensively into their warning program until the start of the severe weather season of 1978. In 1980 they began surveying the counties in post-storm searches for severe weather reports. This was accomplished by contacting all civil defense agencies, local police departments and others. One last factor was the more extensively trained spotter network established after 1980. A change in station managers in 1979 could also have contributed to a new philosophy which contributed to the above-mentioned results.

b. EASTERN COLORADO

Eastern Colorado provides a markedly different scene than the states further east. Much of the area is sparsely populated except for the Front Range communities from Denver northward. About the only source of storm reports away from the Front Range is along the widely scattered main highways where the small communities are located.

Due to the nature of the severe thunderstorms that develop over the high plains of eastern Colorado (high frequency of hail) the reflectivity levels on the WSR-57 radar at Limon, Colorado are frequently quite high. Since reflectivity levels of 6 are often used as a signature of severe thunderstorms, the counties of eastern Colorado have been the national leaders in number of warnings in both the BV and AV periods. In the BV period there were just 10 counties in the country that had over 100 warnings issued and all were in eastern Colorado (Fig. 7) with Lincoln county totaling 205.

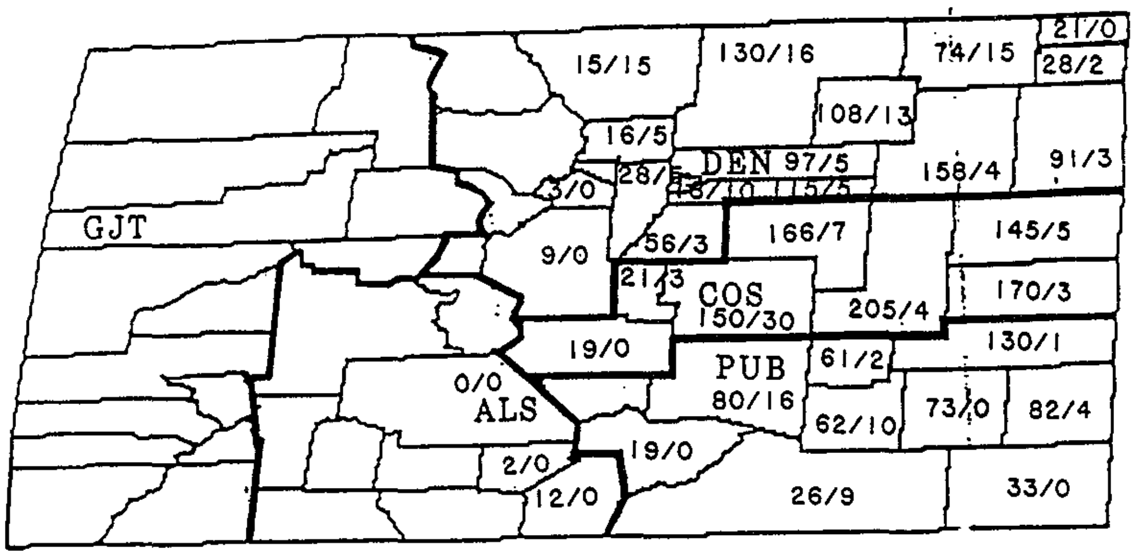


Figure 7. Colorado county severe thunderstorm and tornado warnings and severe thunderstorm reports for the period from 1976-1979.

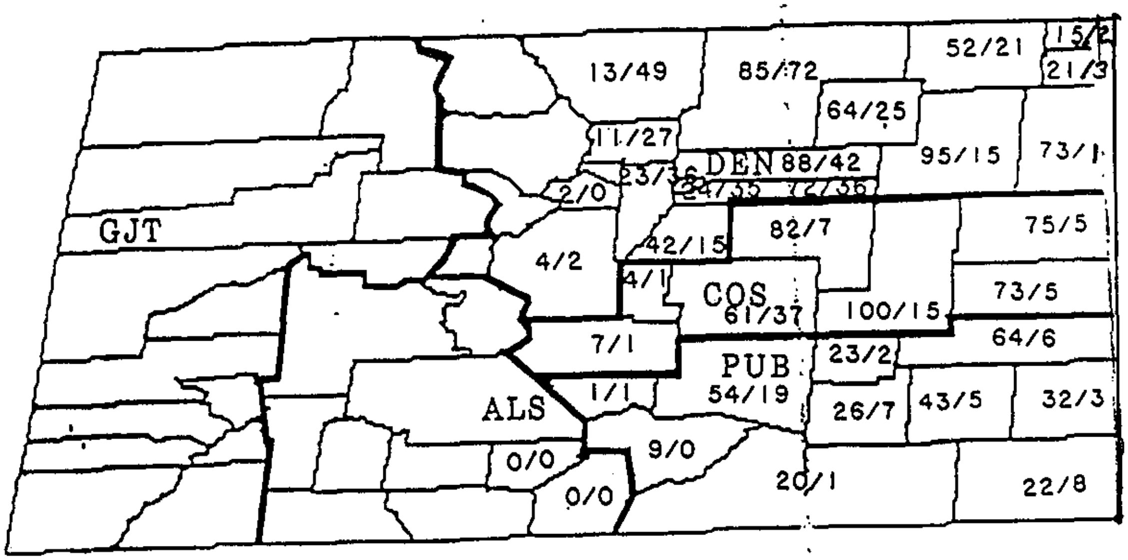


Figure 8. Same as Fig. 7, except for the period from 1980-1983.

Figure 7 also indicates the number of reports in the same period and it <u>appears</u> that there was a serious problem of over warning. Lincoln county which had over 200 warnings only reported four events of severe weather, not necessarily in a warning. To a lesser extent this was the case throughout all of the eastern Colorado counties. The warnings in many cases very likely were valid however the population is too thin to provide adequate ground truth.

The criteriom for issuing warnings was tightened in the AV period and Figure 8 shows the results. The only county in Colorado as well as the country during the AV period exceeding 100 warnings was Lincoln. The number of severe reports had also increased which brought about improved verification. However, by comparing the AV (Fig. 9) normalized for area report analyses the values were still far smaller than those in other states examined.

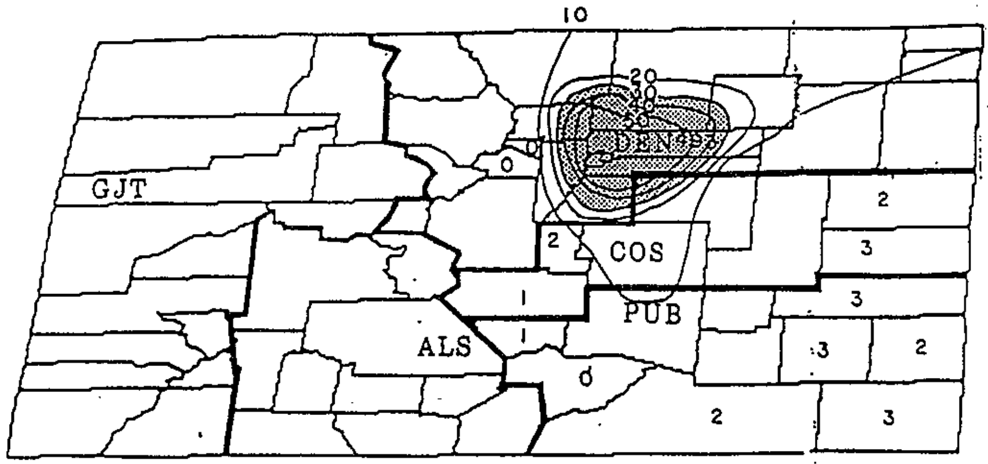


Figure 9. Analysis of Colorado severe thunderstorm reports per 1000 sq. mi. for the period from 1980-1983. Heavy outline is the area of county warning responsibility for the station indicated.

Outside Denver county which contains the Denver metropolitan area, the only region with a substantial number of reports is the area encompassed by the PROFS (Prototype Regional and Observation Forecast System) meso-network of surface observations. (The PROFS mesonet is a densely instrumented area east of Denver and Boulder, Colorado that is used in the testing of new forecasting technology.) This area was frequently scoured for reports by the storm chasers from the Environmental Research Laboratory. PROFS was not active during the BV period.

The marked improvement in the AV period of finding severe reports in the counties east of Denver where considerable effort was expended suggests that similar results could be obtained in the other counties of eastern Colorado if the same care was taken to find reports of severe weather.

Due to the wide open spaces throughout much of eastern Colorado the post-storm surveys, that are done with considerable success in other areas, would be much less effective with the exception of the PROFS MesoNet. However, the question can be asked, "Even if the report is not likely to get into the system, should the forecaster with the warning responsibility let that influence his decision on issuing a warning?" Even though there are relatively few people, shouldn't they also have the right to expect warnings for impending severe weather? The National Weather Services Operations Manual (NWS, 1982) states that "the National Weather Service has no greater statutory responsibility than preparing and distributing forecasts and warnings of impending severe weather". This applies to all of the United States regardless of population.

c. OHIO

In recent years, NWS offices in Ohio have been consistently producing some of the best verification marks in the country. The key to their success apparently has been taking an approach similar to Columbia, Missouri but on a statewide scale. Through personal communication with the Warning Preparedness Meteorologist at WSFO Cleveland it was learned that there are vigorous spotter training and post-storm follow-up programs. Also, communications are very good between the NWS and the public safety organizations.

The BV period (Fig. 10) shows the only regions of Ohio of significant report collection occurring in the large metropolitan counties. In the AV period (Fig. 11) a tremendous increase occurred, particularly in northern and western Ohio.

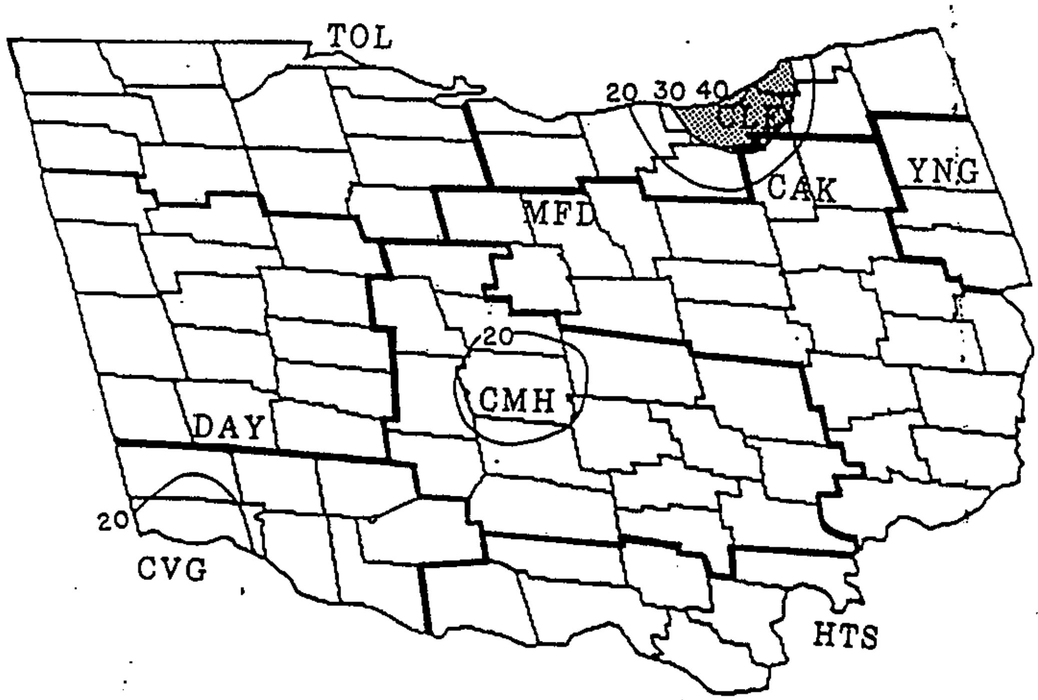


Figure 10. Analysis of Ohio severe thunderstorm reports per 1000 sq. mi. for the period from 1976-1979. Heavy outline is the area of county warning responsiblity for the station indicated.

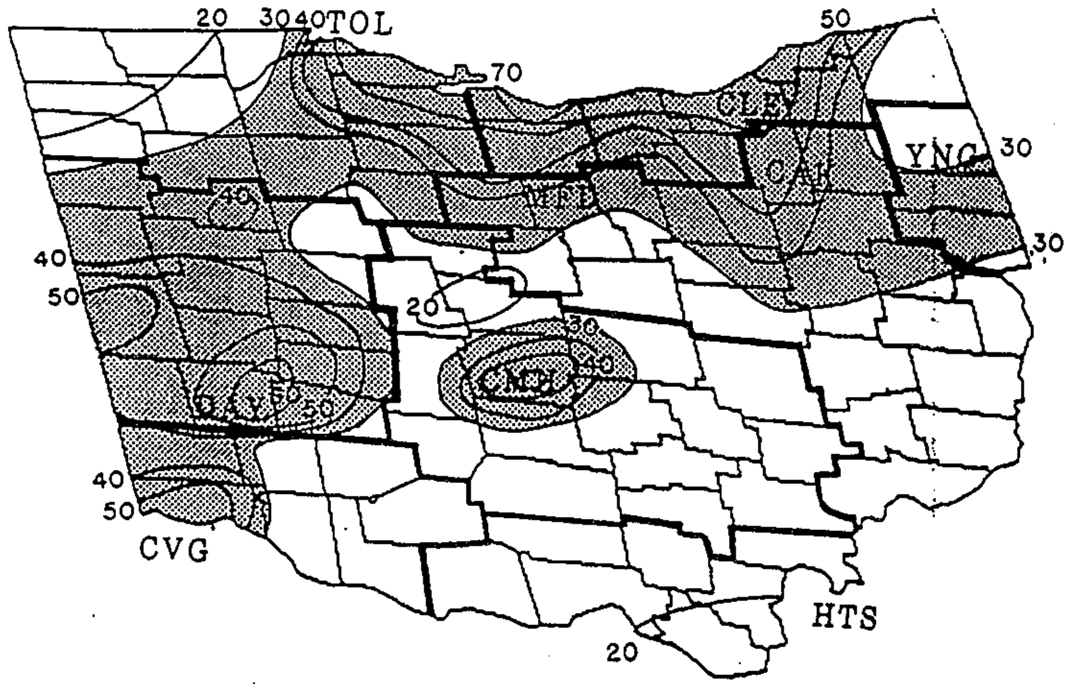


Figure 11. Same as Fig. 10, except for the period 1980-1983.

Also, the bullseye pattern around populated counties was only obvious at CMH (Columbus). Though not shown here, the county warning frequency did not change much from the BV period to the AV period. This suggests that the warning philosophy changed little but much increased effort was taken to get severe weather reports into the verification system.

4. EFFECTS ON VERIFICATION

When analyzing the distribution of severe reports across the country a strong bias is evident toward populated counties and distance from the warning office. This relationship shows up dramatically near many of the metropolitan areas. One such example is Pulaski County in Arkansas (where Little Rock is located) where 108 severe thunderstorm reports/1000 sq. mi. were recorded in the AV period (Fig. 12). Of all the counties bordering Pulaski, the greatest number of normalized reports was only 34 with just six reports in Grant County, just southwest of Pulaski.

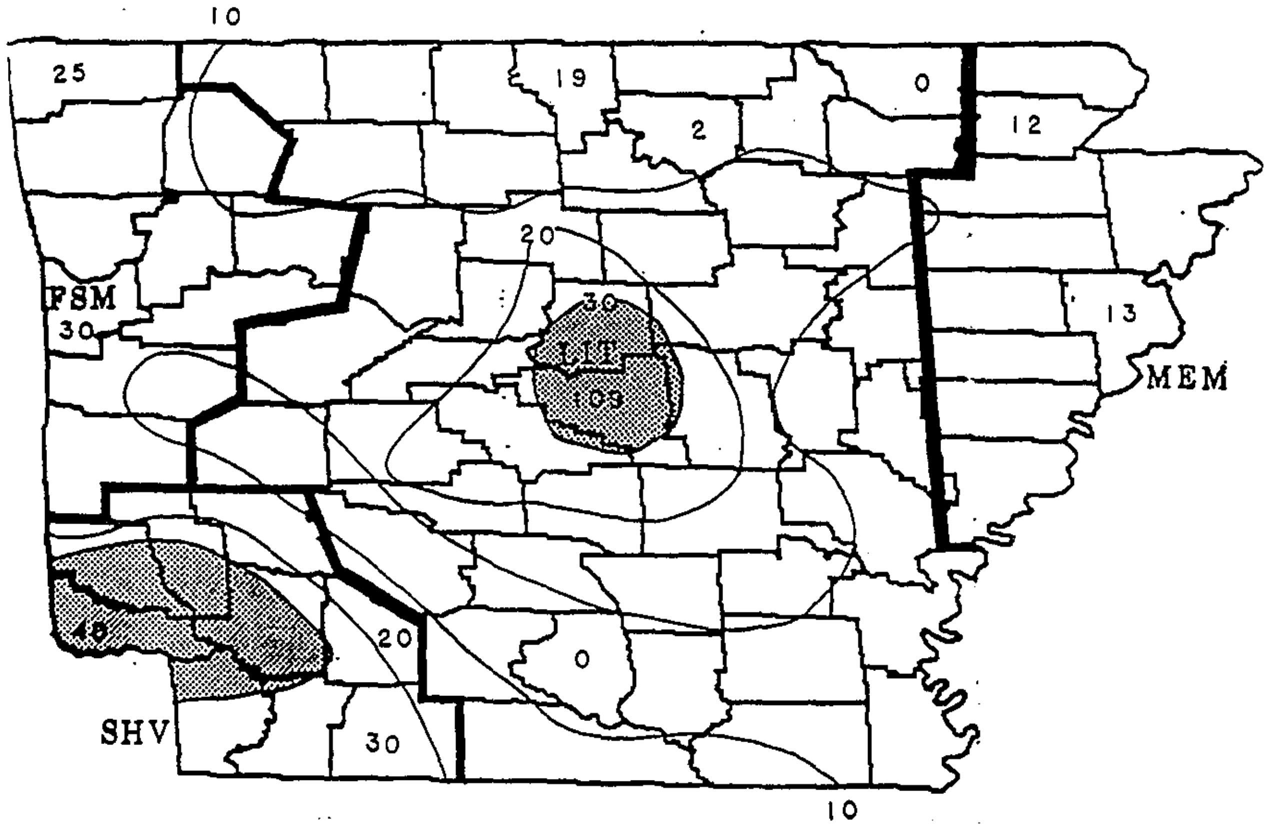


Figure 12. Analysis of Arkansas severe thunderstorm reports per 1000 sq. mi. for the period from 1980-1983. Heavy outline is the area of county warning responsiblity for the station site indicated.

Though Grant County is of comparable size to Pulaski, it has less than 5% of the population. Thus, a severe thunderstorm event has a much better chance of being detected in Pulaski County than in Grant County. Also, with the warning location of Little Rock in Pulaski County the likelihood is much greater that a severe event will be reported due to better spotter networks, etc.

With reference to the reports and warnings of severe thunderstorms, perhaps the most important point is that the severe thunderstorm data base is so incomplete and unrepresentative of the true distribution, I feel that there is enough evidence of the biases in the data to recommend that a comparison of warning verification on the regional or national level should not be done.

Does the verification system result in improved public service? To answer this depends on what kind of action the system encourages the warning offices to take to improve their scores. One approach which several offices have implemented is to literally scour the countryside after the storms have ended to search for ground truth.

This has been quite fruitful for such stations as Columbia, Missouri; Shreveport, Louisiana; Oklahoma City, Oklahoma; and others. Even though many of these stations have increased the number of warnings during the AV period, they have been able to improve their verification scores by digging for the severe reports. By following this path it likely has resulted in improved public service as it provides positive feedback to the warning office and encourages them to warn for those outlying counties.

However, an office can also show increase skill by selectively issuing warnings. By being more reluctant to issue a warning for those counties that are known to be poor report producers due to low population, poor communications or whatever reason, an office would be able to increase its apparent skill scores. It is obvious from the data presented in this paper that there is a tremendous variation from county to county as to the number of severe reports received. This results in a very biased severe storm climatology. Though there were no reports from a particular storm, it does not necessarily mean that the storm was not severe. A storm from which no reports were received would more likely be a severe storm in a poor report producing county than an urban or high report producing county. This can then lead to the conclusion that rural counties are much less likely to have warnings issued on severe storms than urban counties from offices that use this warning philosophy.

Another problem is created by the varying report collection methods across the nation and the resultant effect on the severe storm climatology. This raises a question as to the credibility of the data base being developed for severe storms.

5. SOLUTIONS

It has been clearly shown that the severe thunderstorm data base is incomplete and unrepresentative. This makes it unfair to evaluate performances of warning offices by comparing verification scores. The question is raised as to what changes are needed to make the warning verification system more responsive to the needs of the forecasters issuing the warnings and the public who is served by them. There does not appear to be a readily apparent solution to this problem. Realizing that due to population disparities it will be very difficult to ever get a completely accurate data base some consideration could be given to weighting the data. Those reports that occur in rural areas would take on more significance than those in a heavily populated area. Clearly, it is evident that comparing one office against another is not a valid approach. Possibly looking at the intra-office scores from year to year would prove to be more meaningful.

Another approach would be to deemphasize how many warnings are verified assuming that the warning criteria used are valid. In the public's perception, a warning quite likely is justified if they experience intense lightning, heavy rainfall or even wind driven small hail. Any given spot is under a warning on such an infrequent basis that the "cry wolf" syndrome may not be a valid problem. In 1984 and 1985, both Shreveport, Louisiana and Oklahoma City, Oklahoma issued more warnings than any other office in the United States, yet they were near or at the top in all verification scores.

Currently there is not a discriminatory method to evaluate the significance of a severe report. As far as the verification system knows, a 3/4 inch report of hail carries as much significance as would a powerful hailstorm that causes 10's of millions of dollars in damage to homes, vehicles, etc., in a large metropolitan area. A wind gust of 50 kt which would normally do only a minimal amount of damage is compared equally to an intense downburst where winds may exceed 100 kt and result in loss of life and millions of dollars in damage. Considering the "significance" of the reports is a very important part of evaluating the service provided to the public, and can be a valuable enhancement to the current verification system. Emphasis in the verification program should be focused on those significant severe events for which the Weather Service has forecast responsibility. These would include the severe thunderstorms that have the potential to threaten life and destroy property. Since it is just a matter of chance where the path of a significant storm will move, the determination of actual damage and casualties associated with a storm are only a partial solution. Any storm which would pose a significant threat to life and property should be separated from the lesser events.

Thus, a stratification of severe events should be done with the verification emphasis on how did the warning system perform in handling the life threatening storms. Two objectives this would accomplish is to make the verification system much fairer to the warning offices and more meaningful to management of the NWS. It would also go a long way in eliminating the temptation of the offices in manipulating the marginal severe reports. There is a much greater likelihood of a significant severe report reaching the severe report data base than a marginal one. It would provide a truer measure as to how the Weather Service does in warning the public on those "significant" severe events that it is charged with.

6. SIGNIFICANT SEVERE EVENT EVALUATION

The criteria used to define significant severe events are as follows:

Tornados - F2 or greater on the Fujita-Pearson(FPP) scale
Wind gusts - 65 kts or greater
Hail - 2 inches in diameter or greater
All events - one fatality, 3 injuries or damage in excess of $50,000 (non-agricultural losses).

Even with significant severe events, there will still be limitations as to detectability. The sparse population in many areas will result in some significant storms remaining undetected. Further, if a storm moves through an urban area, there is a much greater likelihood of damage exceeding $50,000. There should, however, be substantially less population and location bias with significant severe events than with non-significant severe events.

The total event data base during 1982-1985 was screened for these significant severe events and the relationship between total severe events and significant severe events is shown in the following table.

YEAR	EVENTS	SIG	SIG/EVENTS
1982	7345	884	12%
1983	8410	963	11%
1984	7349	924	13%
1985	8000	959	12%

A marked increase in the total number of tornados observed in the United States in the 1950's was directly related to the establishment of the severe local storm forecasting program in the early 1950's. The increase was primarily due to an improvement in the data gathering system rather than an actual increase in the number of tornados. It can be noted (Fig. 13) that even with the greater number of total tornados, the incidence of killer tornados changed little. Since 1952, the variation in significant tornado occurrence from year to year, most likely has been related to the actual weather conditions, rather than demography. Any tornado that results in a fatality is almost certain to make it into the data base.

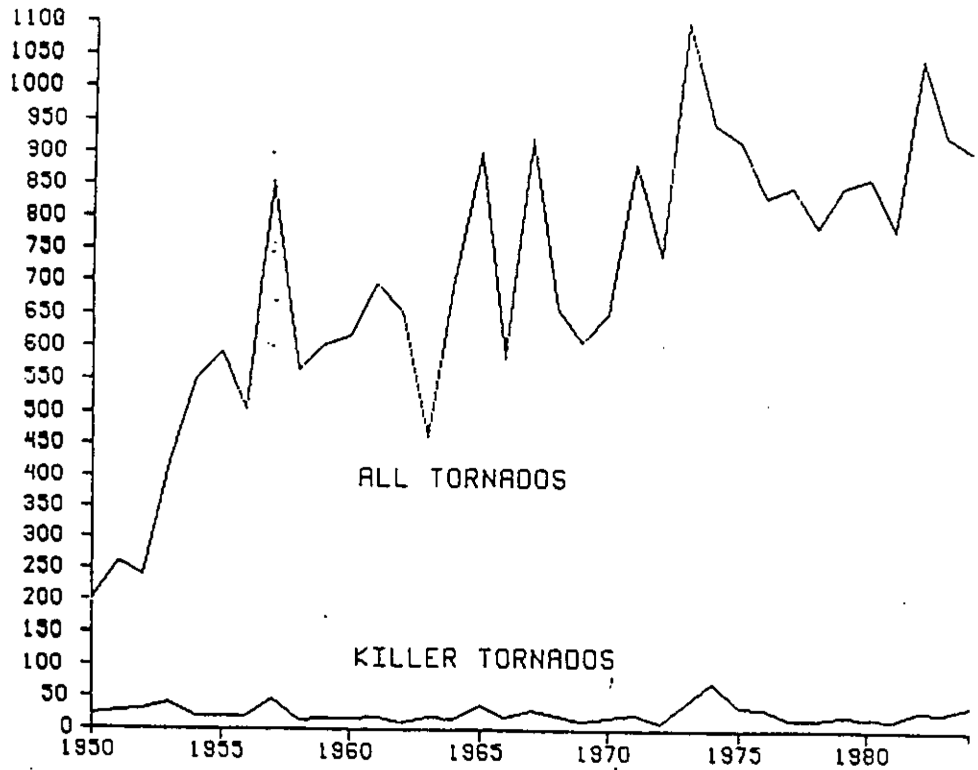


Figure 13. Annual tornado versus killer tornados 1952-1984.

A similar "cause and effect" relationship can be applied to the dramatic increase in severe thunderstorm reports in recent years following the advent (in 1979) of the NWS warning verification program.

It is logical to assume that a greater percentage of the significant severe events will be detected and entered into the severe storm data base than the less significant severe events. In densely populated regions, there is a good likelihood that nearly all reports, both significant and marginal, will find their way into the data base. However, in the rural or sparsely populated areas, the chances are greater that only a significant severe report will be identified because of its more dramatic effect on life and property.

7. ADVANTAGES OF USING THE PROBABILITY OF DETECTING A SIGNIFICANT EVENT

The PODS is a statistic that is computed the same as the POD (Donaldson, 1975) except that the significant events are used in place of all severe events.

The addition of the PODS to the verification output can benefit both the meteorologist and management. It provides a more meaningful evaluation of the services provided to the public through the watch and warning system of the NWS. One of the problems with the current system is that it discourages the issuance of warnings in poor report producing regions. As has been discussed there are many areas of the country where warnings are extremely difficult to verify. By switching the emphasis from whether a warning verified to whether a SIGNIFICANT report occurred in a warning will encourage a meteorologist to warn on sound criteria, regardless of where the storm is located.

Warning verification was initiated for a variety of reasons, including the perception that there was a serious over-warning problem in the NWS. The high false alarm ratios that were initially calculated substantiated this perception. A natural reaction was to suggest that the warnings were being issued based on unreliable identification criteria. The fact that the storm may indeed have been severe but unreported was not given strong consideration. Lemon (1979) stated that "some of the high false alarm rates in the current warning techniques may simply result from inadequacies in severe storm event reporting. Thus, if a greater effort is made to establish severe weather occurrence information, the high FAR (Donaldson, 1975) may decrease and an apparent improvement may result".

Without an increase in detection capability, there are only two ways to reduce the FAR: 1) to issue smaller areal warnings (covering fewer counties), or 2) issue fewer warnings. Figure 14 shows the relationship between the number of counties warned in the U.S. and the number of severe events per year. Note that there is no particular trend in the past 10 years as to the number of counties warned while at the same time there has been a dramatic increase in the number of severe events being reported. This shows that the improvement in skill scores resulted from a big increase in detectability rather than a decrease in number of warnings.

WSFO Oklahoma City (OKC) began a more aggressive warning program (Devore et al., 1985) in the early 1980s, followed by an extensive post storm survey program beginning in 1983. An examination of the warning statistics for OKC since 1976 produces some interesting observations.

OKLAHOMA CITY WARNING STATISTICS

YEAR	EVENTS	CO WRNGS	POD	FAR	CSI
1976	116	270	.450	.840	.090
1978	109	321	.500	.910	.070
1982	258	563	.508	.801	.167
1983	499	551	.729	.508	.416
1984	509	568	.786	.423	.499
1985	558	543	.774	.346	.549

In the 10 year period 1976-1985, there has been a doubling of the number of counties warned per year. At the same time, there has been more than a four fold increase in the number of events reported annually. In particular the number of severe events virtually doubled between 1982 and 1983, the year that OKC began their post storm survey procedure. Note also that the FAR decreased from 84% in 1976 when there were only 270 warnings issued, to 42% in 1984, when a total of 568 were issued.

Part of this improvement can be attributed to both scientific and technological improvements in the warning issuance procedures at OKC. However, a significant portion of the increase must also be attributed to OKC's extensive follow-up surveys conducted after the fact (Only those counties that were warned are contacted for events). While their 1970's FAR statistics suggests an over warning problem, the imporved statistics in the 1980's point toward a previous weakness in the report gathering system.

Unfortunately not all stations have shared the success that OKC has enjoyed since initiating their post storm searches. In many of the sparsely populated areas of the country, particularly in the western U.S., most storms still go undetected.

Examining the PODS's should provide a more realistic appraisal of the warnings quality. In 1984, Denver CO and Jackson MS both had outstanding PODS's with only fair POD's. Both stations issued warnings for all of their significant events in 1984, 12 in Jackson and 7 in Denver. Personal communication with each station indicates that their policy is to issue warnings whenever the warning criteria are met, with little concern for the verification potential.

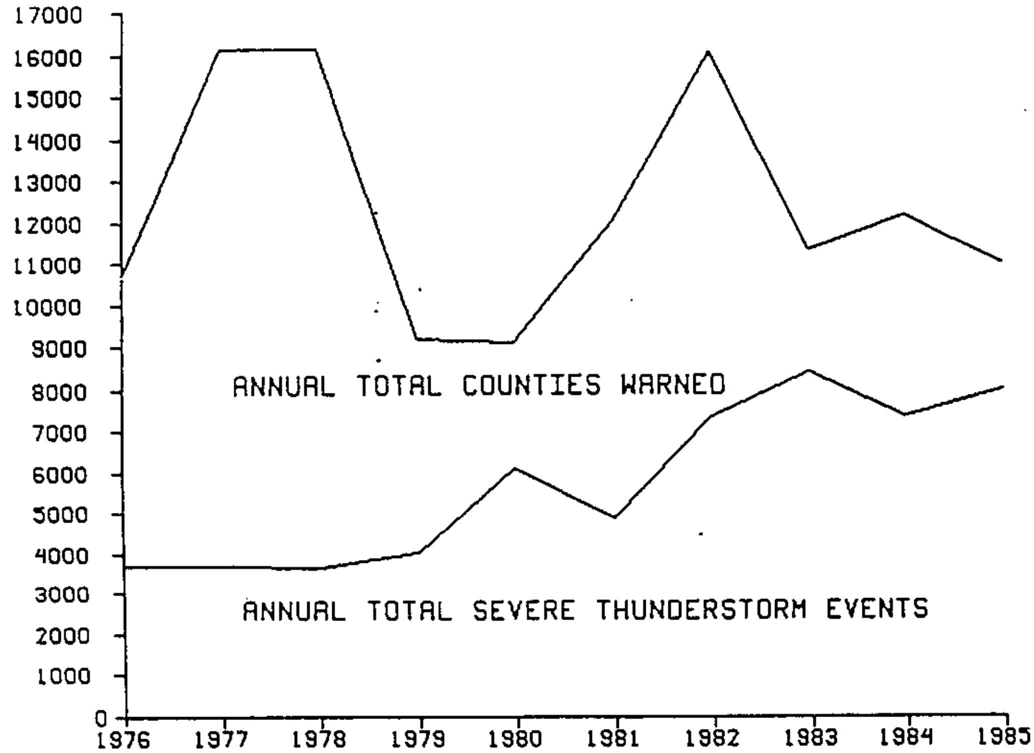


Figure 14. Annual number of counties warned vs annual number of severe events detected 1976-1985.

8. POSSIBLE TECHNIQUES FOR UTILIZING THE PODS.

Appendix A lists the POD AND PODS skill score data for all the warning offices in the country for 1983-85, with the exception of some of the offices particularly in the west who did not report a significant event during the two-year period. Also included are the number or reports and significant reports in each stations area of responsibility for each year. By relating the POD and FAR with the PODS, a better assessment of a warning program may be made.

The following are some personal preliminary observations on how scores may be compared to give some insight into the effectiveness of the warning program. Since the number of significant storms is much less than the total number of storms, the PODS statistic will typically be based on a smaller sample, particularly for a short time frame (i.e. one year). Thus it will take several years of significant data to draw more than just preliminary conclusions.

1) If warnings are biased toward populated areas, then the POD would likely be greater than the PODS. This is because in areas with low population, only significant severe events would likely be reported. Therefore, reports of unwarned significant events in rural areas will reduce the overall PODS, while unwarned non-significant events likely are never reported and do not affect the POD.

2) If the warnings were being issued based on bad criteria, then the FAR would be high; POD and PODS, low. This would be difficult to apply where report gathering is poor.

3) If a strictly objective warning program were operating with no consideration given to event detectability and the criteria are good, then the PODS would likely equal or exceed the POD, and the FAR should primarily reflect the nature of the report gathering system. Since unpopulated areas report primarily significant events and a good warning program would likely detect these events, then this would add to the overall PODS.

4) The better the report gathering system, the smaller the difference between the PODS and the POD. And at stations such as OKC and SHV, such efficient report collecting systems are in place that the POD exceeds the PODS, even with a low FAR. This is a result of the ability to search out the non-significant events in unpopulated areas that have been warned.

9. WATCHES AND THE PODS

In the past 5 years, there have been steady improvements in the tornado and severe thunderstorm watch skill scores. As seen in figure 15 more than 80% of all watches have been verifying with at least one severe report occurring within the watch. This can be attributed to at least two factors.

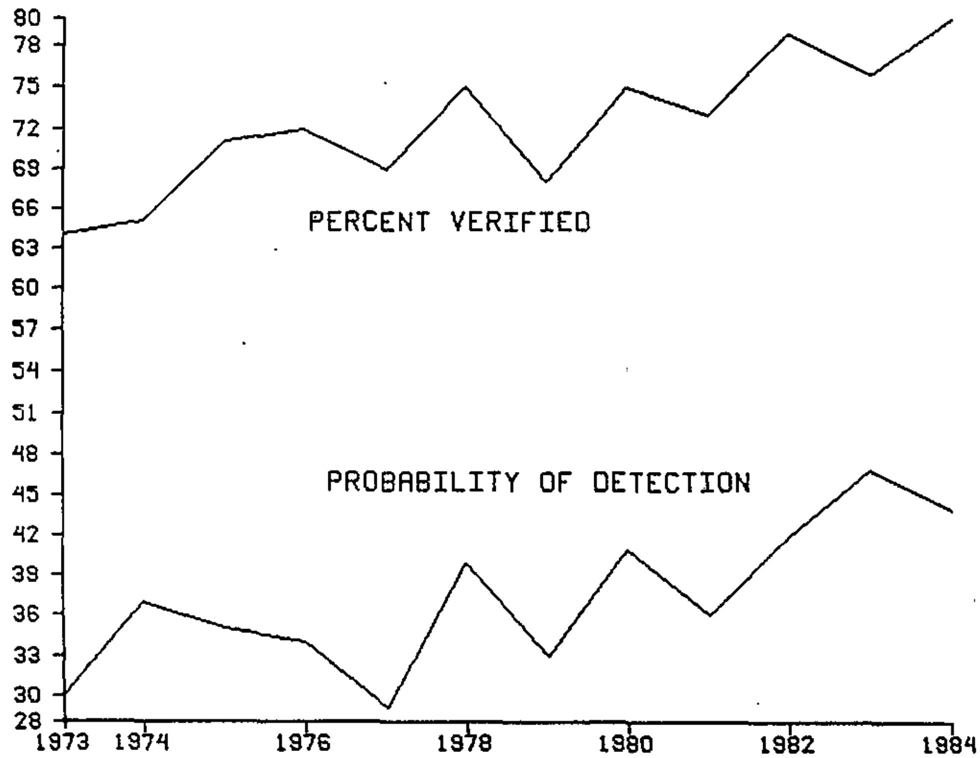


Figure 15. The percent of all watches verified vs the probability of detection of severe events in watches 1973-1984.

First the arrival of the Centralized Storm Information System (CSIS) in 1982 enabled forecasters to access and interpret data at a much faster rate than ever before. This enabled watches to be issued with greater precision and timeliness. The 2nd factor has been the dramatic increase in the number of events reaching the verification data base. This results in the likelihood of more watches being verified, and thus, higher skill scores.

Since watches are forecasts by definition and since a degree of uncertainty exists in all forecasts, it follows that not all watches should be expected to verify, even if a complete knowledge of actual severe activity were possible.

When better than 80% of all watches are verifying, it is then valid to suggest that perhaps not enough watches are being issued. As in the warning program, there might be more reluctance to issue a watch in sparsely settled areas than around larger cities. This probably is not as serious a problem with watches as it is with warnings because of the larger areal coverage of watches. Another contributing factor to high verification scores is that the small lead time (i.e. waiting for the activity to develop before issuing), which allows the watch to be more accurately positioned.

Again, as with warnings, the primary gauge of the quality of the service provided would be to evaluate watches with regard to SIGNIFICANT severe events. Statistics on the PODS of watches will be included in later works on this subject. However, many significant events do not occur in watch areas. If there were less emphasis put on the FAR of watches, and more on service evaluation, there would likely be less reluctance to issuing watches in those situations that result in some of the significant events.

10. CONCLUSIONS

Realizing that due to population disparities it will be very difficult to ever get a completely accurate data base, some consideration could be given to weighting the data. Those reports that occur in rural areas would take on more significance than those in a heavily populated area.

Another approach would be to deemphasize how many warnings are verified assuming that the warning criteria used are valid. In the public's perception a warning quite likely is justified if they experience intense lightning, heavy rainfall or even wind driven small hail. Any given spot is under a warning on such an infrequent basis that the "cry wolf" syndrome may not be a valid problem.

Instead the emphasis in the verification program should be focused on those significant severe events that the Weather Service is charged with warning the public on. These would include the severe thunderstorms that have the potential to threaten life and destroy property. Since it is just a matter of chance where the path of a significant storm will move, the determination of actual damage and casualities associated with a storm are only a partial solution. Any storm which would pose a significant threat to life and property should be seperated from the more minor events.

By incorporating the PODS in the service evaluation of the watch and warning program in the NWS, the meteorologist will be encouraged to more objectively warn the public on impending severe thunderstorms.

There should be a resultant increase in the number of watches and warnings issued in the more sparsely populated regions. The possible increase in overforecasting and its economic impact should be more than offset by the improved detection of life threatening events.

The 1985 LFTAC (Line Forecasters Technical Advisory Committee) also expressed concern about the manner in which severe weather is verified. They stated that "the statistics do not accurately reflect how well we perform and that these statistics have negative effect on morale. The results of this study certainly validate their concern. Much thought needs to be given as to what the verification program is trying to accomplish. There is certainly a question at the present time whether the public's and the forecasters best interests are being served as the program is now structured.

11. ACKNOWLEDGEMENTS

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13. FIGURES

Figure 1. Annual tornado and wind and hail reports in the United States from 1955-1983.

Figure 2. Total number of severe thunderstorm reports 1980-1983 in the United States with the percentage change from the period 1976-1979.

Figure 3. Analysis of Missouri severe thunderstorm reports per 1000 sq. mi. from 1976-1979. Heavy outline is the area of county warning responsibility for the station indicated.

Figure 4. Analysis of all Missouri county severe thunderstorm and tornado warnings for period 1976-1979. Heavy outline is the area of county warning responsibility for the station indicated.

Figure 5. Same as Fig. 2, except for the period 1980-1983.

Figure 6. Same as Fig. 3, except for the period 1980-1983.

Figure 7. Colorado county severe thunderstorm and tornado warnings and severe thunderstorm reports for the period from 1976-1979.

Figure 8. Same as Fig. 7, except for the period from 1980-1983.

Figure 9. Analysis of Colorado severe thunderstorm reports per 1000 sq. mi. for the period from 1980-1983. Heavy outline is the area of county warning responsibility for the station indicated.

Figure 10. Analysis of Ohio severe thunderstorm reports per 1000 sq. mi. for the period from 1976-1979. Heavy outline is the area of county warning responsibility for the station indicated.

Figure 11. Same as Fig. 10, except for the period 1980-1983.

Figure 12. Analysis of Arkansas severe thunderstorm reports per 1000 sq. mi. for the period from 1980-83. Heavy outline is the area of county warning responsibility for the station site indicated.

Figure 13. Annual tornado versus killer tornados 1952-1984.

Figure 14. Annual number of counties warned vs annual number of severe events detected 1976-1985.

Figure 15. The percent of all watches verified vs the probability of detection of severe events in watches 1973-1984.

APPENDIX A

CENTRAL REGION

	1983				1984				1985			
STA	RPT	SR	POD	PODS	RPT	SR	POD	PODS	RPT	SR	POD	PODS
ABR	51	4	.45	.25	18	2	.39	0	81	7	.49	.57
ALO	34	4	.38	0	65	7	.59	1.00	29	3	.52	.33
APN	14	0	.36	-	3	0	.33	-	1	0	1.00	-
BFF	40	10	.43	.50	13	3	.46	0	41	5	.29	.40
BIS	123	24	.49	.63	42	2	.43	.50	55	7	.60	.57
CHI	49	3	.51	.67	53	8	.47	.38	34	3	.41	.33
CNK	63	3	.60	.67	78	2	.74	.50	100	17	.79	.82
COS	1	1	0	1.00	22	2	.50	.50	28	8	.54	.63
COU	94	7	.62	.71	106	4	.76	1.00	64	10	.72	.80
CPR	6	2	.17	0	20	3	.35	1.00	3	0	.33	-
CYS	18	3	.22	0	18	3	.44	.67	13	0	.46	-
DBQ	25	7	.04	0	21	4	.38	0	24	3	.42	1.00
DDC	22	6	.27	0	26	2	.69	1.00	58	7	.69	.29
DEN	222	20	.57	.66	95	7	.58	1.00	96	13	.47	.62
DLH	61	15	.34	.47	52	6	.65	.83	60	6	.67	1.00
DSM	101	12	.37	.33	150	46	.46	.61	129	10	.49	.30
DTW	78	8	.36	.38	20	2	.40	.50	48	1	.50	0
EVV	27	4	.37	.25	74	6	.49	.67	53	6	.53	.83
FAR	132	21	.64	.67	88	15	.73	.87	123	9	.59	.78
FNT	35	4	.31	.25	23	9	.43	.56	14	0	.79	-
FSD	63	9	.35	.67	79	10	.46	.30	126	14	.71	.79
FWA	35	3	.57	.67	15	2	.40	0	50	4	.78	1.00
GLD	25	9	.28	.22	43	5	.44	.40	35	11	.63	.91
GRB	42	7	.36	.29	44	9	.50	.67	21	6	.71	.83
GRI	46	10	.20	.10	72	13	.65	.62	90	18	.47	.56
GRR	57	1	.49	1.00	15	0	.47	-	36	1	.72	1.00
HON	26	6	.39	.33	51	9	.43	.44	60	8	.52	.50
HTL	10	2	.20	0	6	0	.33	-	6	0	1.00	-
ICT	59	3	.49	.33	114	8	.71	.63	128	15	.72	.87
IND	115	6	.46	.33	64	0	.58	-	120	8	.58	.75
INL	47	2	.30	.50	17	0	.53	-	25	0	.68	-
ISN	34	6	.32	.17	20	5	.70	.60	9	0	.78	-
JKL	27	2	.26	0	14	1	.64	0	25	0	.72	-
LAN	58	1	.33	0	25	2	.32	0	45	1	.62	0
LBF	51	8	.35	.38	46	17	.57	.35	51	14	.49	.43
LEX	36	0	.44	-	20	0	.45	-	23	0	.30	-
LNK	8	2	0	0	25	9	.36	.36	38	12	.47	.58
LSE	53	6	.59	.83	28	6	.54	.67	16	3	.19	0
MCI	54	4	.56	.50	65	13	.37	.08	70	8	.37	.13
MKE	100	19	.46	.53	97	24	.66	.75	52	10	.46	.50
MKG	24	0	.33	-	9	0	.33	-	19	1	.58	1.00
MLI	21	4	.09	.25	15	1	.40	0	19	1	.58	1.00
MQT	18	2	.11	0	10	2	.10	0	19	1	.74	0
MSN	76	7	.68	.57	91	18	.56	.50	45	9	.44	.44
MSP	107	20	.63	.75	66	9	.36	.22	78	3	.50	.33
OFK	23	5	.22	.20	58	17	.55	.59	46	9	.52	.44
OMA	58	10	.38	.50	52	11	.56	.55	67	12	.64	.67
PIA	17	1	.18	0	17	0	.53	-	28	1	.21	0
PUB	0	0	-	-	17	4	.18	.25	11	0	.27	-
RAP	62	18	.39	.56	41	6	.32	.50	46	9	.78	.33
RFD	16	0	.06	-	14	1	.36	0	13	0	.54	-
RST	48	6	.21	.33	60	7	.45	.86	39	1	.26	-
SBN	43	1	.37	0	9	1	.33	0	32	3	.56	1.00
SDF	122	0	.21	-	51	4	.20	0	50	5	.22	.20
SGF	88	5	.66	1.00	79	3	.57	1.00	70	15	.56	.53
SHR	26	0	.04	-	18	2	.17	.50	11	5	0	0
SPI	27	0	.26	-	38	2	.40	0	29	0	.31	-
SSM	11	0	.09	-	6	1	0	0	5	0	.20	-
STC	75	11	.28	.46	31	6	.36	.33	27	4	.52	.75
STL	107	20	.62	.70	244	34	.71	.74	82	11	.46	.18
SUX	40	5	.40	.40	30	8	.47	.63	28	0	.25	-
TOP	74	18	.35	.61	69	18	.49	.61	74	8	.57	.63
VTN	10	3	.40	.33	2	0	0	0	8	2	.50	.50
AVG	3270	410	.43	.47	2886	421	.53	.55	2975	362	.54	.57

APPENDIX A

SOUTHERN REGION

	1983				1984				1985			
STA	RPT	SR	POD	PODS	RPT	SR	POD	PODS	RPT	SR	POD	PODS
ABI	66	9	.57	.67	23	2	.44	.50	70	12	.73	.75
ABQ	4	0	0	-	3	0	0	-	3	0	.33	-
ACT	31	4	.42	.25	53	8	.57	.50	32	3	.50	1.00
AGS	40	6	.38	.50	26	1	.35	0	22	0	.36	-
AHN	24	5	.25	.20	89	5	.85	1.00	61	6	.66	.50
AMA	75	12	.23	.25	35	2	.46	.50	70	19	.49	.63
ATL	27	5	.30	.40	90	14	.57	.71	69	10	.55	.70
AUS	49	8	.27	.38	32	8	.31	.38	24	3	.67	.67
BHM	108	13	.44	.46	102	17	.66	.77	128	19	.67	.63
BNA	27	3	.26	.33	79	6	.39	.17	66	9	.27	.33
BPT	53	17	.49	.71	28	1	.25	0	32	4	.34	.50
BRO	28	9	.50	.56	28	9	.50	.57	6	0	1.00	-
BTR	70	17	.46	.53	24	11	.54	.55	9	0	.22	-
CHA	27	6	.30	.17	23	1	.30	1.00	31	7	.48	.57
CRP	16	5	.56	.80	9	0	.44	-	28	5	.46	.80
CSG	33	3	.33	.67	34	4	.47	.25	29	3	.52	.67
DAB	28	10	.46	.50	8	0	.38	-	17	0	.53	-
DRT	16	3	.56	1.00	3	0	.67	-	11	2	.36	0
ELP	4	0	.25	-	1	1	0	0	6	1	.00	0
ESF	20	4	.35	.25	11	0	.55	-	2	0	.50	-
FMY	7	1	0	0	3	0	0	-	3	0	.00	-
FSM	39	6	.41	.50	74	20	.58	.60	60	3	.58	.33
FTW	222	36	.59	.72	264	26	.67	.65	236	22	.67	.55
GLS	18	1	0	0	2	0	0	-	6	0	.67	-
HOU	104	38	.59	.58	44	3	.59	1.00	56	1	.71	0
HSV	49	5	.49	.40	61	5	.64	.80	83	9	.58	1.00
JAN	96	16	.33	.63	71	12	.47	1.00	98	8	.56	.38
JAX	51	12	.20	.17	25	3	.32	0	10	2	.30	.50
LBB	54	8	.44	.63	11	1	.36	1.00	59	10	.58	.60
LCH	37	10	.41	.50	28	8	.38	.75	34	1	.35	1.00
LIT	193	20	.34	.55	173	19	.47	.47	136	11	.48	.55
MAF	21	1	.48	0	5	0	.40	-	60	8	.45	.38
MCN	34	4	.38	.25	61	1	.61	1.00	47	3	.66	1.00
MCO	24	5	.58	.80	13	1	.54	0	5	1	0	0
MEI	37	5	.38	.60	23	1	.65	0	53	1	.62	0
MEM	32	8	.19	.25	150	20	.33	.45	81	7	.27	.29
MGM	61	6	.48	.33	87	10	.66	.70	74	2	.57	.50
MIA	52	9	.29	.44	17	1	.29	1.00	21	0	.24	-
MOB	75	8	.35	.25	58	5	.64	.80	72	10	.56	.50
NEW	48	7	.40	.43	38	7	.58	.71	69	3	.41	0
OKC	499	59	.73	.75	509	59	.79	.73	558	66	.77	.74
PBI	8	3	.38	.67	7	0	.29	-	12	2	.08	.50
PNS	37	7	.19	.43	10	2	.50	1.00	14	2	.36	.50
SAT	50	9	.60	.67	60	9	.50	.33	45	5	.51	.40
SAV	19	1	.16	0	32	4	.44	.75	30	0	.60	-
SHV	361	59	.74	.76	531	32	.83	.78	362	23	.83	.83
SJT	28	2	.57	1.00	13	1	.54	0	32	8	.53	.63
SPS	52	9	.56	.44	18	4	.67	.50	47	5	.66	.80
TBW	50	13	.16	.23	39	0	.13	-	28	5	.07	0
TLH	33	2	.15	.50	3	1	.33	0	16	1	.50	0
TUL	112	13	.59	.62	107	21	.56	.52	143	16	.52	.50
TUP	14	2	.29	.50	24	8	.38	.50	33	4	.21	0
VCT	11	0	.09	0	8	2	.88	1.00	1	0	0	-
AVG	3292	533	.50	.56	3272	370	.61	.63	3361	347	.60	.59

APPENDIX A

EASTERN REGION

STA	1983 RPT	SR	POD	PODS	1984 RPT	SR	POD	PODS	1985 RPT	SR	POD	PODS
ABE	7	3	.57	1.00	18	7	.56	1.00	36	2	.81	1.00
ACY	10	1	.60	1.00	1	0	1.00	-	8	0	.50	-
ALB	79	3	.32	.67	32	0	.34	-	34	1	.44	1.00
AVL	4	2	0	0	13	0	.07	-	65	2	.74	.50
AVP	2	0	.50	-	3	1	0	0	22	6	.46	.50
BDL	10	0	.50	-	10	1	.60	0	24	2	.67	.50
BDR	17	0	.06	-	7	0	0	-	1	0	0	-
BGM	44	3	.39	1.00	8	1	.13	0	10	0	.40	-
BKW	20	2	.30	.50	2	0	.50	-	3	0	.33	-
BOS	27	0	.37	-	9	0	.22	-	8	0	.38	-
BTV	22	5	.32	.60	2	1	0	0	4	0	.25	-
BUF	51	1	.43	1.00	22	0	.59	-	37	6	.78	.83
BWI	49	7	.14	.43	19	0	.21	-	21	0	.05	-
CAE	61	3	.18	0	80	19	.64	.79	84	10	.39	.30
CAK	80	5	.78	.40	30	0	.50	-	54	1	.63	0
CAR	24	3	.46	0	4	0	0	-	5	0	0	-
CHS	26	1	.35	1.00	38	5	.74	.40	34	3	.32	0
CLE	66	8	.82	.73	13	3	.62	.33	42	8	.69	.63
CLT	19	4	.11	0	26	0	.27	-	101	13	.61	.46
CMH	37	5	.43	.80	23	6	.52	.33	37	4	.62	.50
CON	26	6	.12	.17	11	0	.09	-	7	1	.14	0
CRW	22	0	.23	-	10	2	.20	0	2	0	0	-
CVG	36	1	.50	1.00	6	0	.17	-	13	2	.23	.50
DAY	34	0	.38	-	12	2	.42	.50	19	8	.47	.50
EKN	23	0	.87	-	12	2	.42	0	4	0	0	-
ERI	18	4	.78	1.00	1	0	0	-	60	29	.87	.83
GSO	27	2	.22	1.00	39	5	.54	.20	117	13	.45	.69
GSP	16	2	.06	0	74	5	.72	.80	65	4	.57	.75
HAR	34	0	.09	-	11	0	.27	-	34	4	.50	.75
HAT		6		.17	28	9	.50	.56	46	6	.43	0
HTS	40	2	.35	0	5	1	.20	0	5	0	.20	-
ILG	16	2	.44	0	10	2	.60	.50	4	1	.25	0
ILM	41	6	.20	.23	57	0	.53	-	49	1	.67	1.00
IPT	7	1	0	1.00	2	0	0	-	8	4	.50	.50
LYH	16	1	.38	0	2	0	.50	-	3	0	.33	-
MFD	25	1	.52	1.00	2	0	0	-	12	2	.50	0
NYC	17	0	.16	-	23	0	.44	-	49	1	.74	0
ORF	8	2	.13	.50	24	2	.92	1.00	6	0	.83	-
ORH	17	0	.30	-	8	2	.13	1.00	11	0	.55	-
PHL	27	1	.30	0	10	0	.30	-	27	1	.33	0
PIT	59	12	.41	.50	28	6	.61	.67	72	6	.85	.83
PVD	9	0	.67	-	1	0	1.00	-	1	0	0	-
RDU	29	1	.03	0	123	14	.66	.57	111	3	.70	.33
RIC	83	9	.35	.11	33	6	.39	.17	26	0	.54	-
ROA	11	2	.18	0	13	3	.46	.33	1	0	0	-
ROC	33	0	.36	-	4	0	0	-	11	0	.82	-
SYR		5		.60	26	1	.69	1.00	24	1	.46	1.00
TOL	57	11	.65	.73	25	3	.32	0	53	10	.62	.30
WBC	50	4	.14	.25	13	1	.08	0	14	2	.36	.50
YNG	31	3	.36	.80	3	1	1.00	1.00	22	8	.64	.88
AVG	1498	155	.38	.45	1022	120	.51	.53	1528	182	.59	.56

APPENDIX A

WESTERN REGION

	1983				1984				1985			
STA	RPT	SR	POD	.PODS	RPT	SR	POD	PODS	RPT	SR	POD	PODS
BIL	20	3	.05	0	23	0	.48	-	10	3	.30	.33
BOI	9	1	0	0	23	1	.17	-	11	1	.09	0
GTF	21	3	.38	.33	10	0	.50	-	12	3	.50	.33
HLN	4	2	0	0	7	0	0	-	3	0	0	-
LAX	9	3	.11	0	10	0	0	-	5	0	0	-
LWS	5	1	0	0	3	1	.67	1.00	2	0	1.00	-
MSO	8	2	.25	0	1	0	0	-	4	0	.25	-
PHX	37	10	.32	.60	16	5	.06	0	12	4	.25	0
SLC	37	0	.30	-	34	1	0	-	33	3	.12	0
TUS	9	4	.56	.50	9	1	0	-	6	0	.33	-
YUM	5	1	.40	1.00	1	0	0	-	4	0	0	-
AVG	258	39	.17	.26	189	13	.17	.08	133	16	.23	.13

STA Warning station
RPT Number of severe thunderstorm events
SR Number of significant severe thunderstorm events
POD Probability of detection of a severe thunderstorm event
PODS Probability of detection of a significant severe thunderstorm event