NOAA TECHNICAL MEMORANDUM NWS NSSFC-27

SEVERE LOCAL STORM WARNING VERIFICATION: 1989

Leo A. Grenier, John T. Halmstad, and
Preston W. Leftwich, Jr.
National Severe Storms Forecast Center
Kansas City, Missouri 64106-2897

May 1990

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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ABSTRACT. Tornado and severe thunderstorm warnings are issued by local offices of the National Weather Service. Routine verification of these warnings is accomplished at the National Severe Storms Forecast Center. This report highlights verification procedures and summarizes national, regional and local verification results for the year 1989.

Stations in the Southern and Central regions have issued most of the warnings and experienced most of the severe local storm events. On a national scale, all verification scores improved. A record number of severe local storm events were confirmed in 1989. After a leveling trend in the Probability of Detection in 1987 and 1988 a strong upward trend is now evident.

1. INTRODUCTION

Severe local storm warnings are issued to the public by more than 200 local offices of the National Weather Service (NWS). These warnings, which are typically based on radar information and/or storm spotter reports, alert the public to an existing tornado or severe thunderstorm. Each designated area of warning responsibility is composed of counties in the vicinity of the local office. Locations of these offices are contained in Operations of the National Weather Service (NWS, 1985). Areas of responsibility are defined in Weather Service Operations Manual, Chapter C-47 (1986). Routine verification of all tornado and severe thunderstorm warnings issued by NWS offices is accomplished at the National Severe Storms Forecast Center (NSSFC) in Kansas City, Missouri. This report summarizes these verification results for the year 1989. Detailed evaluation of results, such as comparisons among individual offices, is beyond the scope of this report.

2. VERIFICATION PROCEDURES

Severe local storm warning verification began at the NSSFC in 1979. Pearson and David (1979) and Kelly and Schaefer (1982) analyzed warning verification statistics back to 1976. In 1982 the NWS formulated a National Verification Plan (NWS, 1982) to provide guidelines for verification of all products issued to the public. The severe local

storm warning verification effort at the NSSFC is an integral part of this national program. Monthly and year-to-date summaries are now routinely provided to national and regional headquarters and to local offices.

The two elements necessary for verification are: (1) issued warnings and (2) event reports. Initially, both warnings and event reports are collected in real time from the Automation of Field Operations and Services (AFOS) computer system. Information concerning events are extracted from surface observations, warning messages, local storm reports (LSR), statements, pilot reports and state weather summaries. Additional reports may be received via newspaper articles and telephone conversations. These reports form a "rough log" of severe local storm events.

Each week, listings of warnings that have been logged and processed at the NSSFC and the "rough log" are transmitted via the AFOS system to local offices for review. The roles of these warning and event summaries in the verification process are discussed in detail by Leftwich and Lee (1984), and updated by Grenier and Halmstad (1986). After reviewing warning lists, local offices send any warning corrections to the Verification Section at the NSSFC. The rough log is an aid for the Warning Preparedness Meteorologist (WPM), at each forecast office, to use in preparing "Storm Data and Unusual Weather Phenomena" (Form F-8). These F-8 reports are the sole source of event reports used in the "smooth log" for official verification. There is one exception in that real-time surface aviation observations (SAO's) containing severe weather reports may be retained in the smooth log. After all forms of information have been compiled, the resulting "smooth log" and warning file are the data bases for official verification.

To qualify as a severe local storm event, a report must satisfy one of the criteria given in Table 1. General guidelines on event reporting may be found in Grenier and Halmstad (1986). For verification purposes, multiple reports of non-tornadic events occurring within 10 statute miles and 15 minutes of each other and in the same county are recorded as one event. All distinct tornadoes are retained as separate events.

Table 1

Criteria for Severe Local Storm Events
Used in Warning Verification

a. Tornado - a rotating circulation touching the ground and associated with a convective cloud.

b. Hail equal or greater than 3/4 inch (1.9 cm) in diameter.

c. Thunderstorm wind gust of at least 50 knots (93 km/h).

d. Thunderstorm wind damage.

Any event that occurs both within a county for which a warning was issued and during the valid period of the warning is a "warned event". Thus, many events can occur during one warning. Any type of severe event (Table 1) can verify either type (tornado or severe thunderstorm) warning.

In current verification procedures, the county is the basic unit of area. A warning in effect for three counties is counted as three "warned counties". At least one severe local storm event occurring during the valid period of a warning in a warned county produces a "verified county". In order to obtain perfect verification, at least one severe local storm event must occur in each warned county.

Once data have been compiled, a four-cell contingency table (Table 2) can be constructed to depict relationships between warnings and events. Various verification statistics can be computed from this contingency table. Primary statistics used in current verification are the Probability of Detection (POD), False-Alarm Ratio (FAR), and Critical Success Index (CSI). They have been adapted from Donaldson et al. (1975).

Table 2

TABLE 2. Two by two contingency table depicting counts of warnings and events.

EVENTS \ WARNINGS	YES	NO
YES	x	y
NO	z	w *

x = warned events
y = unwarned events
z = unverified warnings
w = no warning, no event

* not used in calculations of verification statistics

The POD, which is a measure of the correctness of the warnings in time and space, is computed as follows:

$$POD = \frac{x}{(x + y)} \quad \text{or} \quad \frac{\text{number of warned events}}{\text{total number of events}} \qquad (1)$$

Values range from "0" to "1" with the higher score indicating greater probability of detection.

The FAR, a measure of overwarning, is computed by:

$$FAR = \frac{z}{(x + z)} \quad \text{or} \quad \frac{\text{number of unverified counties}}{\text{number of warned counties}} \qquad (2)$$

Values range from "0" to "1" with the lower score indicating a lesser degree of overwarning.

The CSI, which is the same as the Threat Score, is given by:

$$CSI = \frac{x}{(x + y + z)} \text{ or } \frac{\text{number of warned events}}{\text{sum of the events and unverified warnings}} \quad (3)$$

Values range from "0" to "1" with the higher score indicating more skill. A graphical depiction of how the CSI reflects both the POD and FAR is given in Appendix B.

Two additional statistics, Percent Verified (PV) and Verification Efficiency (VE), provide additional information concerning verification warnings. The Percent Verified (PV) is defined as:

$$PV = \frac{\text{number of verified counties}}{\text{number of warned counties}} \times 100 = (1 - \frac{z}{x+z}) \times 100 \quad (4)$$

The PV is also equivalent to 100(1-FAR). Values range from "0" to "100". Verification efficiency represents an average of the POD and PV, and provides a straight forward measure of combined success in verifying warnings and covering events with valid warnings. It is calculated as

$$VE = 0.005 \ (PV + 100 \times POD) \quad (5)$$

and ranges from "0" to "1".

Even though a severe local storm may occur in a particular county, sparseness of population can decrease the chances that an event is reported. Schaefer and Galway (1982) addressed biases reflected in the tornado climatology across the United States. Hales and Kelly (1985) discussed possible effects of variations in reporting of hail and thunderstorm wind gust events upon verification results. Recently, Doswell and Burgess (1988) noted several problems relating to the F-scale rating system and the occurrence of very long track tornado events. Results of these studies demand that caution be exercised in directly comparing verification results between local offices, and regions that have different population densities or different meteorological regimes.

3. NATIONAL STATISTICS

Table 3 summarizes warning verification data for the contiguous United States during 1989. A total of 10,408 severe local storm events were reported, and 11,956 counties were warned. This is the greatest number of confirmed severe weather events since verification began in 1979, and it is 1683 more than the previous high year of 1986. The counties warned total of 11,956 is the highest annual count since 1984. Tornadoes totaled 856, which is 72 more than the 30-year annual average of 786. Nationwide, approximately 62% of the severe local storm events occurred in warned counties, and at least one event was observed in 46% of the warned counties. The resulting national CSI was .37 with a VE of .55.

Additionally, the Southern Region severe event total of 5173 was 1679 higher than their previous high year. Five Southern Region stations with areas of responsibility in the Red River Valley of Oklahoma and Texas accounted for 2209 warned counties and 1966 severe local storm events. This means that 2.3% of all stations were responsible for 18.5% of the national total of warned counties and 18.9% of the severe. Approximately 75% of the totals occurred in April, May, and June.

Table 3

National Severe Local Storm Warning Verification Data: 1989

Counties Warned	11,956
County Warnings Verified	5,459
Severe Local Storm Events	10,408
Warned Events	6,468
FAR	.53
POD	.62
CSI	.37
Percent Verified	46
VE	.55

Figures la, b, c, and d show the distributions by station of some of these statistics. Only those stations that issued at least one warning or had one event occur in their area of responsibility were included in the raw distribution. Because stations with minimal activity tend to fall into the extremes of the raw distribution, the data were also filtered using the following criteria.

(1) FAR...contains only those stations that issued 6 or more warnings for the year.

(2) POD...contains only those stations that had 6 or more severe events occur in their area of responsibility.

(3) CSI...contains only those stations that meet the criteria in (1) or (2).

(4) VE....contains only those stations that meet the criteria in (1) or (2).

A comparison of the raw distribution to the filtered distribution is shown in Figures la, b, c and d respectively. Median values are shown for both the raw and filtered distributions of the FAR, POD, CSI and VE.

Figure 2 depicts the trend in national statistics since 1979, the first full year in which warnings were gathered. All curves showed significantly slower changes in 1987 and 1988 than in previous years. This may have been partially due to reduced severe weather activity and the bias that the CSI exhibits in relation to frequency of events. (Gilbert,1884)

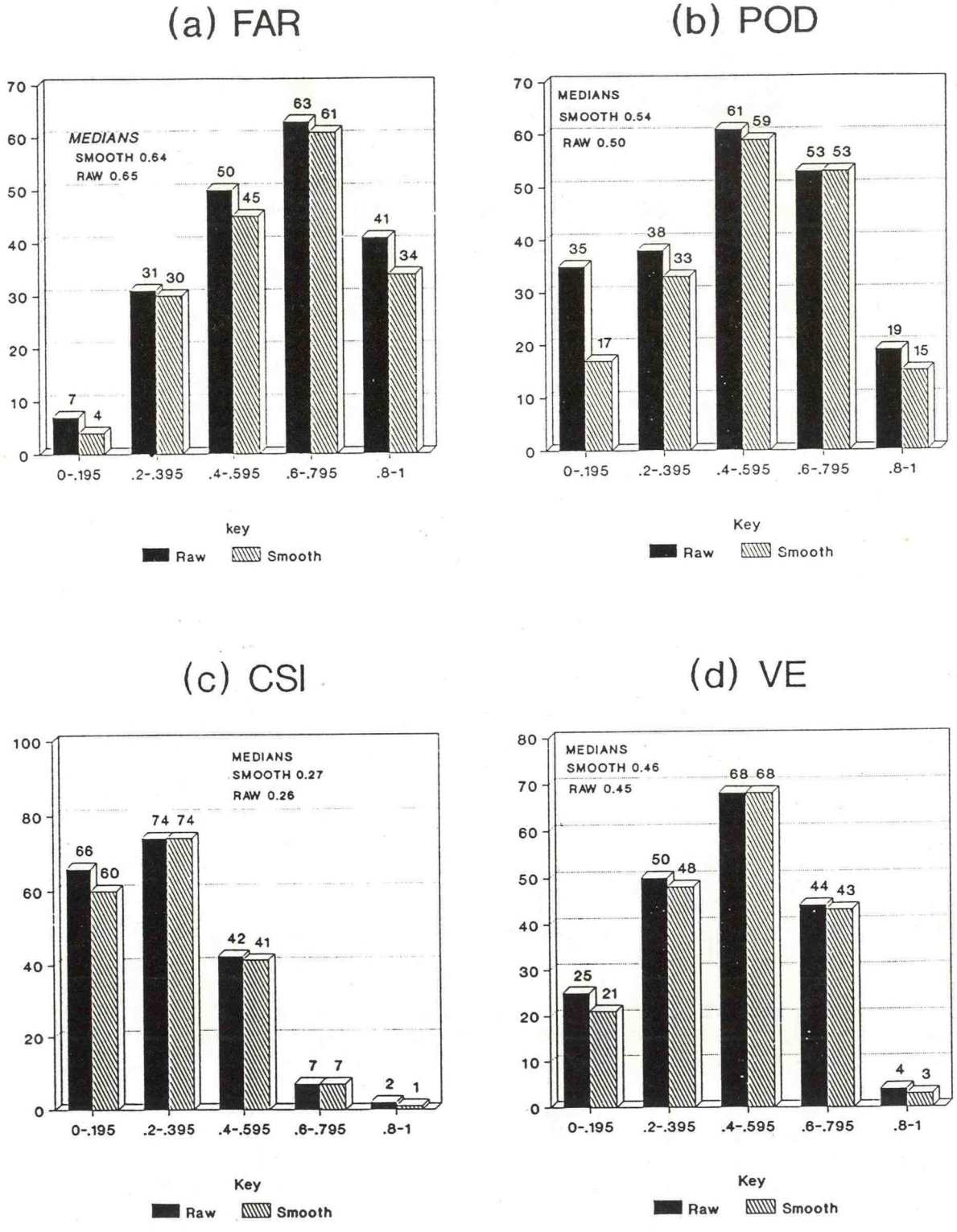

Figure 1. Frequency distributions of severe local storm warning verification statistics for 1989.

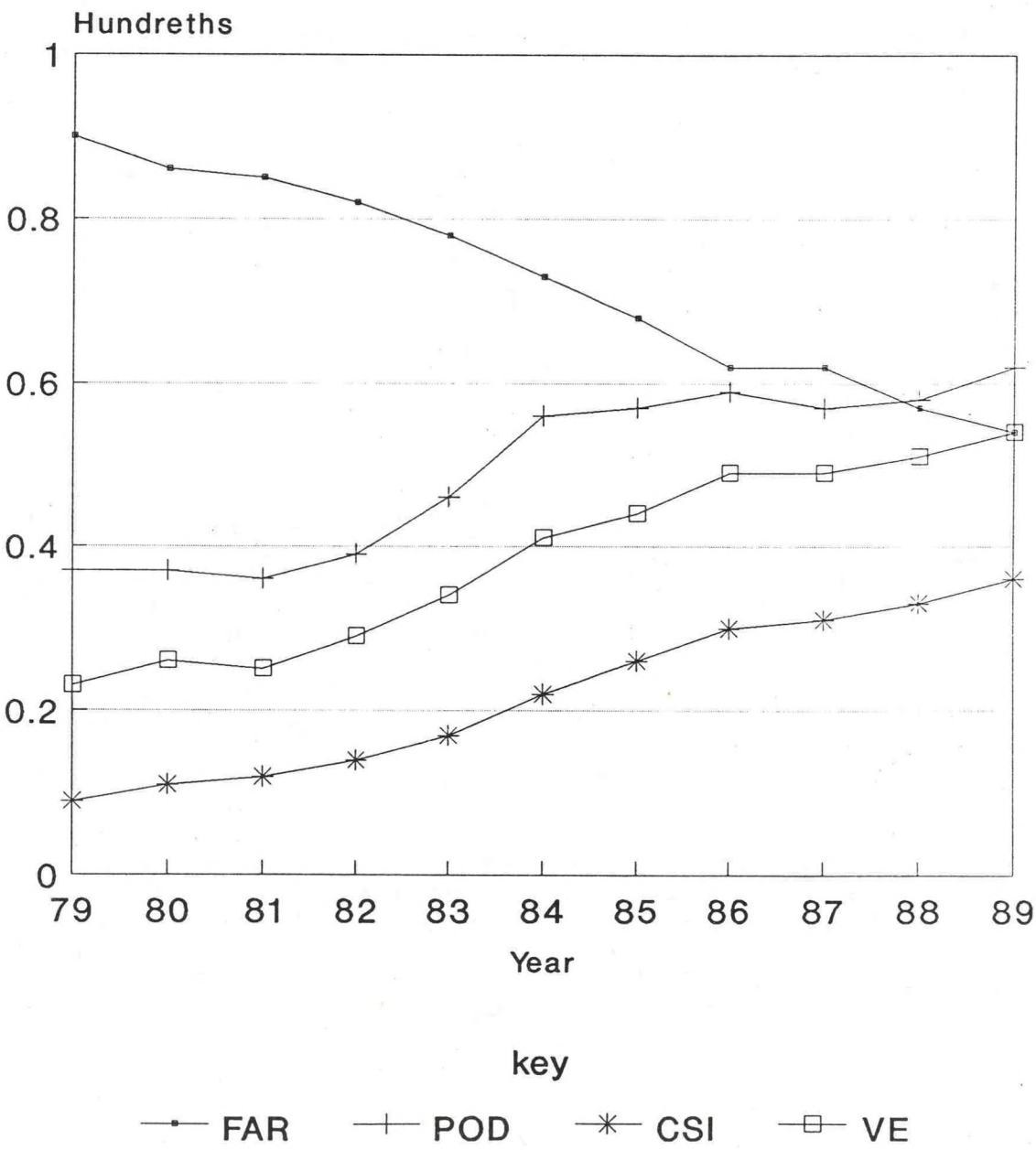

Figure 2. Severe Local Storm Warning Verfication.

During 1989, tornadoes caused 49 fatalities and 1270 injuries in the United States. The fatalities and injuries totals are significantly higher than the 1986 record lows of 15 and 536 respectively, but they are significantly lower than the 30-year annual averages of 82 fatalities and 1673 injuries. This is in spite of the fact that the 1989 tornado total was 9 percent higher that the 30-year annual average. As shown in Table 4, 59 percent of all tornado fatalities and 77 percent of all tornado injuries occurred within a valid severe local storm warning. Severe thunderstorm wind gusts caused another 29 fatalities and 504 injuries. Of these, 48 percent of the fatalities and 36 percent of the injuries occurred within a warned area. Figure 3 shows the 1989 distribution of tornadoes and fatalities by state.

Table 4
Severe Local Storm-Related Fatalities and Injuries
Relative to Valid Warnings: 1989

	Tornado		Severe Thunderstorm	
	Fatalities	Injuries	Fatalities	Injuries
Total Number	49	1270	29	504
Within Valid Warnings	20	981	14	183
% Within Warnings	59	77	48	36

Figure 4 shows the number of event reports received in three categories for a 30 year period. While the number of tornadoes has remained relatively steady, the number of wind/hail reports and the total events have generally been increasing. The 1989 severe local storm events total of 10,408 is 2.5 times greater than the 1979 total. Originally, a severe event was identified as a duplicate if it met the following criteria; (1) it was in the same county, (2) it was within 10 statute miles and 15 minutes of another report, (3) it was the same type of non-tornadic phenomena, i.e. hail or wind (Leftwich and Lee, 1984). It was later noted that a severe wind and severe hail report from the same severe thunderstorm caused the storm to be counted twice. In an effort to eliminate previously retained duplicate storms the "same type" requirement was dropped at the beginning of the 1986 severe weather year (Grenier and Halmstad,1986). One might have interpreted the 1987 and 1988 decline in event totals as a leveling trend, but they were unusually quiet severe weather years. It now appears that the increasing trend in total events remains with us along with the improved verification percentages in all categories.

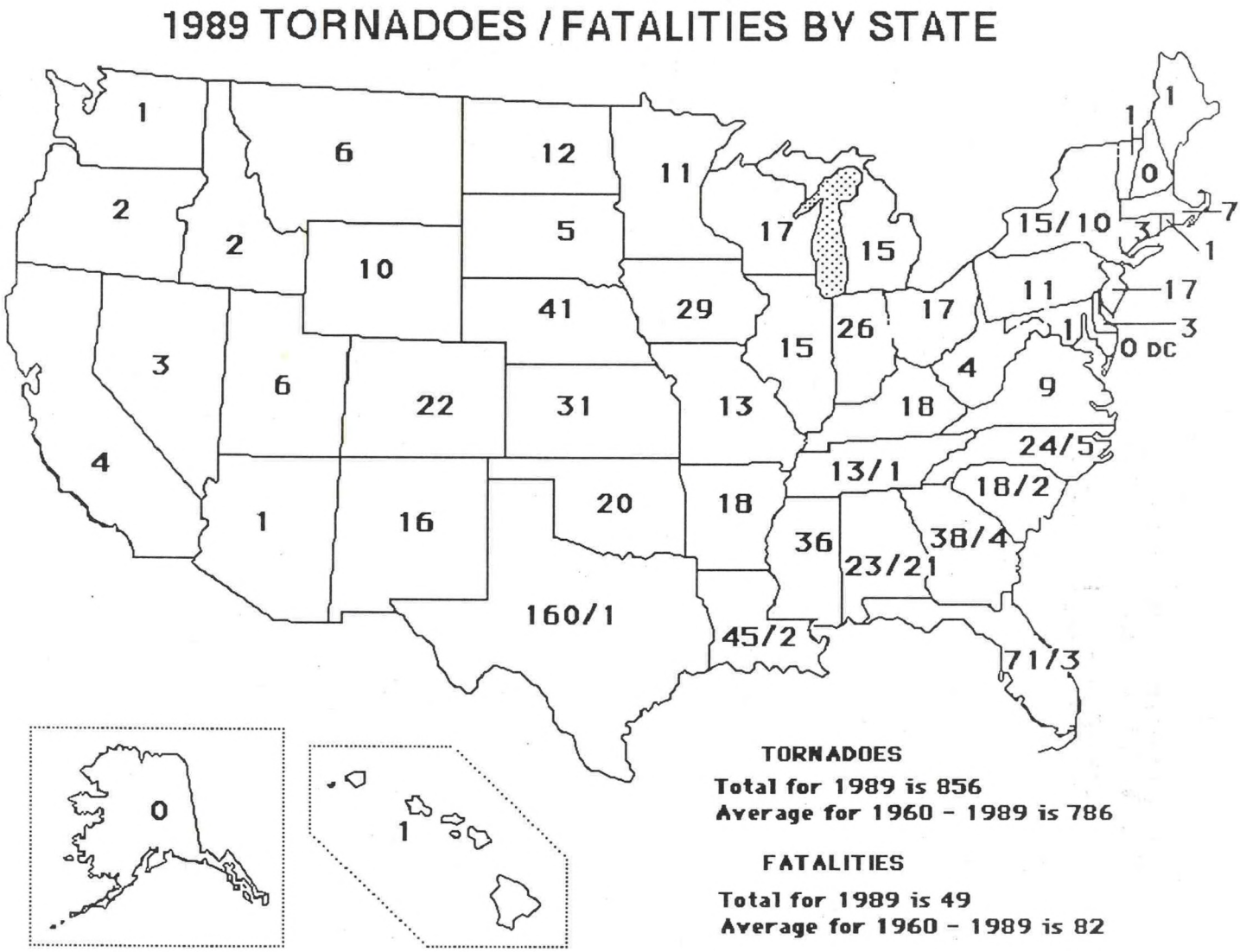

Figure. 3 Map of tornadoes/fatalities for 1989

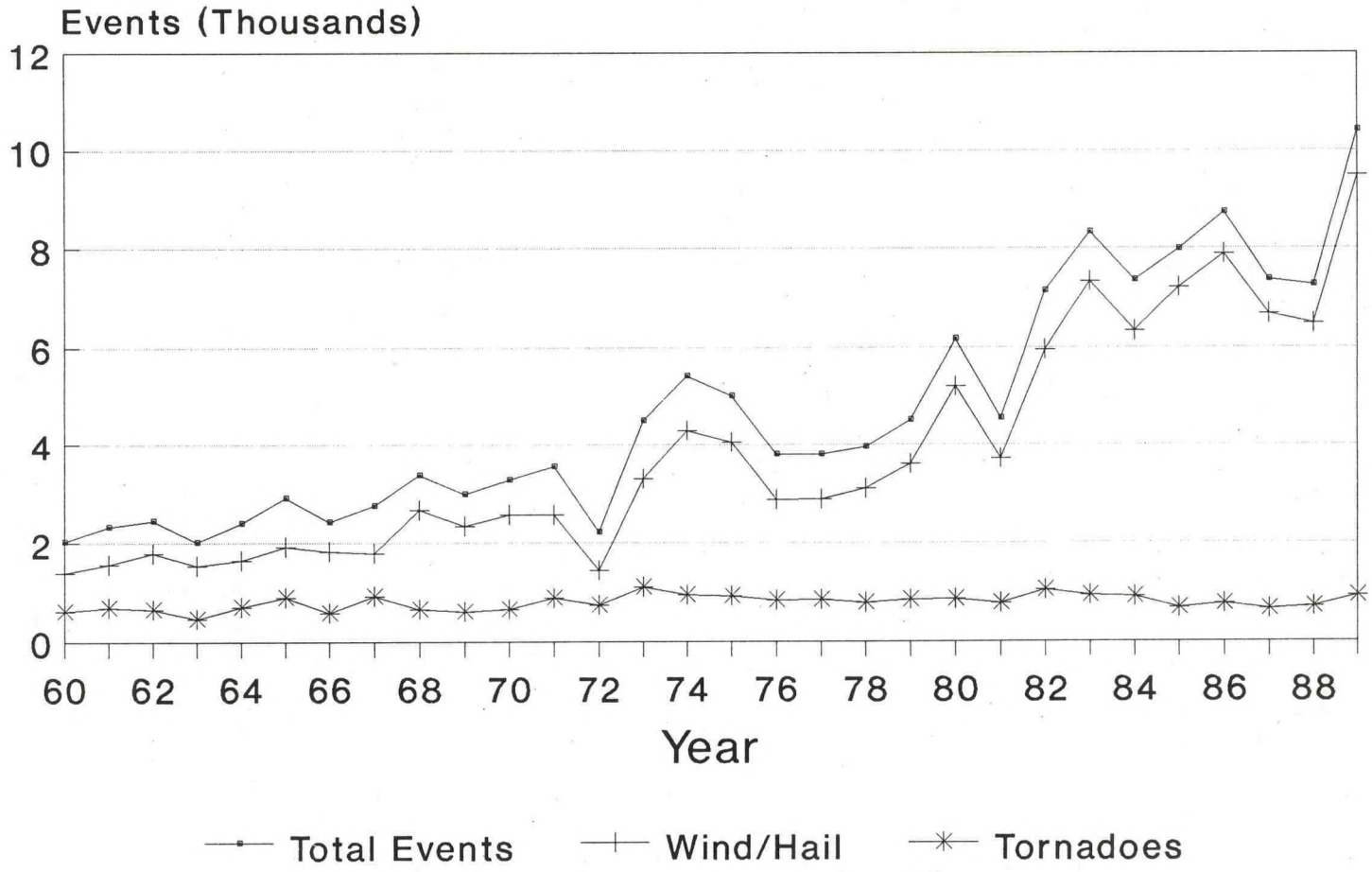

Figure 4. Annual severe event totals.

4. REGIONAL STATISTICS

Table 5 summarizes warning verification data for the four contiguous NWS regions. Maps depicting the states included within each region are contained in Operations of the National Weather Service (NWS, 1985). As in previous years, severe local storm events were more numerous in the Central and Southern Regions than in the other two regions. This is in agreement with the climatologies by Kelly et al. (1978) and Kelly et al. (1985). Accordingly, these regions typically issue more warnings. Consistent percentage contributions of each region to the national totals for each variable are noted again during 1989. For example, the Southern Region issued 50.6% of the county warnings during 1989. This region also had 56.6% of the verified counties, 49.7% of the severe events and 55.8% of the warned events. Figure 5 shows a regional distribution of Severe Local Storm Warnings and Events.

Table 5

Regional Severe Local Storm Warning Verification Data: 1989 Numbers in parentheses are percentages of national totals for each item.

	Central	Eastern	Southern	Western
Counties Warned	3694 (30.9)	1983 (16.6)	6057 (50.7)	222 (1.8)
County Warnings Verified	1321 (24.2)	1004 (18.4)	3088 (56.6)	46 (0.8)
Severe Local Storm Events	2845 (27.3)	2171 (20.9)	5173 (49.7)	218 (2.1)
Warned Events	1551 (24.0)	1261 (19.4)	3608 (55.8)	48 (0.8)
FAR	.64	.49	.49	.79
POD	.55	.58	.70	.22
CSI	.28	.37	.42	.12
Percent Verified	36	51	51	21
VE	.45	.54	.60	.21

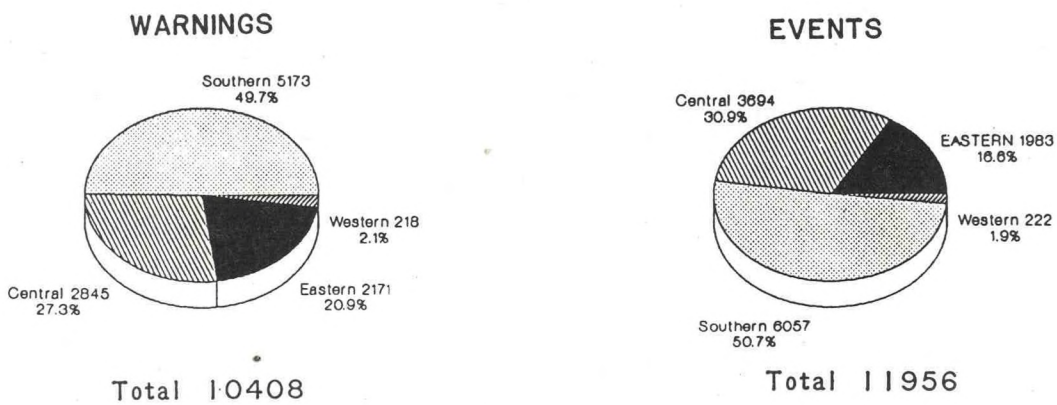

Figure 5. Severe Local Storm distribution by region

5. LOCAL STATISTICS

Appendix A lists severe local storm warning verification data for local NWS offices. Station names for the call-letter identifiers are listed in Appendix A of Operations of the National Weather Service (NWS, 1985). This list includes those offices that either issued at least one severe local storm warning or recorded at least one severe local storm event within its area of responsibility during 1989. A warning is counted for the office issuing that warning. A severe local storm event is counted for the office in whose area of responsibility that event occurs. As an example, office A issues a warning for a county in the area of responsibility of office B. Then, three severe local storm events occur in that county during the valid period of the warning. Office A is credited with a warned county, and office B is credited with three warned events. This accounting procedure can result in an office that issues no warnings having a POD greater than zero in Appendix A.

There are often wide variations in numbers such as warnings issued and severe local storm events from one office to another. Computed statistics reflect differences in both severe local storm reporting and meteorological regimes, as well as the warning skills of the forecasters. As stated previously, these factors demand that caution be exercised in any comparisons of verification results with those of other offices.

6. SUMMARY

Official verification of tornado and severe thunderstorm warnings issued by local NWS offices is accomplished at the National Severe Storms Forecast Center. Monthly and year-to-date reports containing summaries of all warnings and events and various verification statistics are provided for national, regional and local use. This report documents national, regional and local verification results for the year 1989.

Since 1979, verification statistics have shown continued improvement with only minor deviations of the POD in 1981 and 1987. The Central and Southern Regions contribute most of the warnings and observed events in national totals. Varying population density and differing meteorological regimes are among many factors that influence verification results. Any direct comparisons of verification statistics with those of other regions or local offices require caution.

7. ACKNOWLEDGMENTS

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Appendix A

Severe Local Storm Warning Verification for NWS Offices: 1989

* * * KEY FOR COLUMN HEADINGS * * *

STN	=	STATION CALL LETTERS
WRND CNTYS	=	WARNED COUNTIES
VERF CNTYS	=	VERIFIED COUNTIES
TOT EVNTS	=	SEVERE LOCAL STORM EVENTS
WRND EVNTS	=	WARNED EVENTS
FAR	=	FALSE ALARM RATIO
POD	=	PROBABILITY OF DETECTION
CSI	=	CRITICAL SUCCESS INDEX
VE	=	VERIFICATION EFFICIENCY

CENTRAL REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	FAR	POD	CSI	VE
ABR	41	10	27	12	0.756	0.444	0.187	0.344
ALO	33	21	39	20	0.364	0.513	0.397	0.575
ALS	0	0	5	0	0.000	0.000	0.000	0.000
APN	15	1	3	1	0.933	0.333	0.059	0.200
ARB	4	1	0	0	0.750	0.000	0.000	0.250
BFF	76	13	30	12	0.829	0.400	0.136	0.286
BIS	65	31	78	39	0.523	0.500	0.323	0.488
CHI	44	5	24	5	0.886	0.208	0.079	0.161
CNK	136	91	135	113	0.331	0.837	0.592	0.753
COS	26	8	24	10	0.692	0.417	0.215	0.362
COU	47	14	23	16	0.702	0.696	0.264	0.497
CPR	17	5	19	8	0.706	0.421	0.209	0.358
CYS	46	13	36	15	0.717	0.417	0.202	0.350
DBQ	28	8	34	15	0.714	0.441	0.210	0.363
DDC	96	52	73	56	0.458	0.767	0.465	0.654
DEN	75	18	76	17	0.760	0.224	0.131	0.232
DLH	31	11	34	17	0.645	0.500	0.262	0.427
DSM	245	102	192	122	0.584	0.635	0.336	0.526
DTW	33	10	27	11	0.697	0.407	0.210	0.355
EVV	120	86	132	94	0.283	0.712	0.556	0.714
FAR	67	18	55	27	0.731	0.491	0.210	0.380
FNT	4	3	15	3	0.250	0.200	0.187	0.475
FSD	118	13	43	13	0.890	0.302	0.088	0.206
FWA	45	20	36	20	0.556	0.556	0.328	0.500
GJT	0	0	6	0	0.000	0.000	0.000	0.000
GLD	65	36	68	43	0.446	0.632	0.419	0.593
GRB	40	12	28	17	0.700	0.607	0.251	0.454
GRI	109	33	73	37	0.697	0.507	0.234	0.405
GRR	12	9	29	10	0.250	0.345	0.309	0.547
HON	60	7	32	7	0.883	0.219	0.082	0.168
HTL	8	2	9	3	0.750	0.333	0.167	0.292

ICT	170	78	115	95	0.541	0.638	0.418	0.642
IND	170	58	150	64	0.659	0.427	0.234	0.384
INL	26	9	14	8	0.654	0.571	0.275	0.459
ISN	22	15	28	21	0.318	0.750	0.556	0.716
JKL	14	6	10	6	0.571	0.600	0.333	0.514
LAN	23	12	25	15	0.478	0.600	0.387	0.561
LBF	59	11	33	14	0.814	0.424	0.149	0.305
LEX	29	5	12	5	0.828	0.417	0.139	0.295
LND	4	2	10	2	0.500	0.200	0.167	0.350
LNK	21	5	23	6	0.762	0.261	0.142	0.249
LSE	9	6	26	12	0.333	0.462	0.375	0.564
MCI	74	25	53	32	0.662	0.604	0.277	0.471
MKE	90	46	76	63	0.489	0.829	0.462	0.670
MKG	20	8	14	7	0.600	0.500	0.286	0.450
MLI	43	13	28	16	0.698	0.571	0.246	0.437
MQT	10	1	1	1	0.900	1.000	0.100	0.550
MSN	89	32	72	42	0.640	0.583	0.286	0.471
MSP	80	23	47	24	0.712	0.511	0.225	0.399
OFK	78	31	50	34	0.603	0.680	0.335	0.539
OMA	91	25	95	28	0.725	0.295	0.166	0.285
PAH	53	33	58	40	0.377	0.690	0.486	0.656
PIA	32	4	9	5	0.875	0.556	0.114	0.340
PUB	48	7	36	10	0.854	0.278	0.106	0.212
RAP	34	11	26	15	0.676	0.577	0.261	0.450
RFD	24	4	14	4	0.833	0.286	0.118	0.226
RST	73	23	54	27	0.685	0.500	0.240	0.408
SBN	48	28	45	31	0.417	0.689	0.462	0.636
SDF	94	22	60	20	0.766	0.333	0.159	0.284
SGF	69	24	50	29	0.652	0.580	0.278	0.464
SHR	2	1	5	1	0.500	0.200	0.167	0.350
SPI	117	7	20	8	0.940	0.400	0.055	0.230
SSM	2	1	5	1	0.500	0.200	0.167	0.350
STC	36	12	25	14	0.667	0.560	0.264	0.447
STL	127	51	84	54	0.598	0.643	0.328	0.522
SUX	28	6	17	6	0.786	0.353	0.154	0.284
TOP	79	23	45	27	0.709	0.600	0.244	0.446
VTN	0	0	5	1	0.000	0.200	0.200	0.200
AIA	...NO SEVERE ACTIVITY...							
CIR	...NO SEVERE ACTIVITY...							
EEW	...NO SEVERE ACTIVITY...							
GCK	...NO SEVERE ACTIVITY...							
LIC	...NO SEVERE ACTIVITY...							
MMO	...NO SEVERE ACTIVITY...							

EASTERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	FAR	POD	CSI	VE
ABE	2	2	32	3	0.000	0.094	0.094	0.547
ACY	43	24	33	32	0.442	0.970	0.549	0.764
ALB	88	64	124	77	0.273	0.621	0.504	0.674

AVL	60	19	42	21	0.683	0.500	0.241	0.408
AVP	1	1	11	1	0.000	0.091	0.091	0.545
BDL	21	5	19	11	0.762	0.579	0.203	0.409
BDR	13	3	3	3	0.769	1.000	0.231	0.615
BGM	59	40	91	63	0.322	0.692	0.521	0.685
BKW	10	5	8	5	0.500	0.625	0.385	0.563
BOS	21	10	32	17	0.524	0.531	0.335	0.504
BTV	39	25	44	29	0.359	0.659	0.481	0.650
BUF	16	8	13	10	0.500	0.769	0.435	0.635
BWI	54	22	55	25	0.593	0.455	0.274	0.431
CAE	98	64	121	73	0.347	0.603	0.457	0.628
CAK	29	18	27	18	0.379	0.667	0.474	0.644
CAR	0	0	3	0	0.000	0.000	0.000	0.000
CHS	28	21	43	26	0.250	0.605	0.503	0.677
CLE	13	7	18	7	0.462	0.389	0.292	0.464
CLT	72	32	67	38	0.556	0.567	0.332	0.506
CMH	42	28	59	30	0.333	0.508	0.405	0.588
CON	9	5	7	6	0.444	0.857	0.508	0.706
CRW	31	14	25	15	0.548	0.600	0.347	0.526
CVG	45	35	46	37	0.222	0.804	0.654	0.791
DAY	22	17	33	21	0.227	0.636	0.536	0.705
EKN	50	14	42	14	0.720	0.333	0.179	0.307
ERI	12	7	18	11	0.417	0.611	0.425	0.597
GSO	106	46	94	53	0.566	0.564	0.325	0.499
GSP	83	63	122	93	0.241	0.762	0.614	0.761
HAR	51	31	65	39	0.392	0.600	0.433	0.604
HAT	76	14	25	15	0.816	0.600	0.164	0.392
HTS	20	10	20	10	0.500	0.500	0.333	0.500
ILG	12	6	15	10	0.500	0.667	0.400	0.583
ILM	72	22	40	24	0.694	0.600	0.254	0.453
IPT	9	9	33	28	1.000	0.848	0.848	0.924
LYH	7	2	30	7	0.714	0.233	0.147	0.260
MFD	5	2	12	2	0.600	0.167	0.133	0.283
NYC	61	46	70	61	0.246	0.871	0.679	0.813
ORF	53	13	45	13	0.755	0.289	0.153	0.267
ORH	17	10	23	17	0.412	0.739	0.487	0.664
PHL	51	32	84	71	0.373	0.845	0.563	0.736
PIT	69	31	54	36	0.551	0.667	0.367	0.558
PVD	0	0	2	0	0.000	0.000	0.000	0.000
PWM	9	6	24	12	0.333	0.500	0.400	0.583
RDU	191	72	162	75	0.623	0.463	0.262	0.420
RIC	87	46	87	44	0.471	0.506	0.349	0.517
ROA	17	6	25	3	0.647	0.120	0.098	0.236
ROC	11	9	14	10	0.182	0.714	0.616	0.766
SYR	16	13	38	22	0.187	0.579	0.511	0.696
TOL	25	5	20	5	0.800	0.250	0.125	0.225
WBC	43	15	42	13	0.651	0.310	0.196	0.329
YNG	14	5	9	5	0.643	0.556	0.278	0.456
7VM	...NO SEVERE ACTIVITY...							
CHH	...NO SEVERE ACTIVITY...							
EWR	...NO SEVERE ACTIVITY...							
PKB	...NO SEVERE ACTIVIYT...							
RDG	...NO SEVERE ACTIVITY...							

SOUTHERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	FAR	POD	CSI	VE
ABI	121	72	107	82	0.405	0.766	0.504	0.681
ABQ	30	23	30	14	0.233	0.467	0.409	0.617
ACT	87	49	93	67	0.437	0.720	0.462	0.642
AGS	69	8	27	7	0.884	0.259	0.087	0.188
AHN	85	65	93	72	0.235	0.774	0.625	0.769
AMA	399	264	363	308	0.338	0.848	0.592	0.755
AQQ	5	3	6	4	0.400	0.667	0.462	0.633
ATL	126	57	172	73	0.548	0.424	0.280	0.438
AUS	99	11	47	13	0.889	0.277	0.086	0.194
BHM	230	104	154	113	0.548	0.734	0.388	0.593
BNA	121	32	46	33	0.736	0.717	0.240	0.491
BPT	50	16	33	18	0.680	0.545	0.253	0.433
BRO	11	0	4	0	1.000	0.000	0.000	0.000
BTR	79	27	53	29	0.658	0.547	0.266	0.444
CAO	0	0	9	6	0.000	0.667	0.667	0.667
CHA	24	9	12	7	0.625	0.583	0.296	0.479
CRP	22	5	8	4	0.773	0.500	0.185	0.364
CSG	48	21	72	23	0.562	0.319	0.226	0.378
DAB	26	5	32	6	0.808	0.187	0.105	0.190
DRT	23	10	21	13	0.565	0.619	0.343	0.527
ELP	5	1	14	1	0.800	0.071	0.056	0.136
ESF	17	3	11	6	0.824	0.545	0.154	0.361
EYW	1	0	1	0	1.000	0.000	0.000	0.000
FMY	0	0	18	2	0.000	0.111	0.111	0.111
FSM	110	53	89	70	0.518	0.787	0.426	0.634
FTW	413	244	414	346	0.409	0.836	0.529	0.713
GLS	15	8	11	9	0.467	0.818	0.477	0.676
HOU	84	18	34	19	0.786	0.559	0.183	0.387
HSV	66	31	53	33	0.530	0.623	0.366	0.546
JAN	263	106	168	120	0.597	0.714	0.347	0.559
JAX	55	16	43	17	0.709	0.395	0.201	0.343
LBB	195	67	121	82	0.656	0.678	0.295	0.511
LCH	77	13	33	15	0.831	0.455	0.140	0.312
LIT	209	98	237	126	0.531	0.532	0.332	0.500
MAF	141	91	161	112	0.355	0.696	0.503	0.671
MCN	65	54	91	62	0.169	0.681	0.598	0.756
MCO	3	3	8	3	0.000	0.375	0.375	0.687
MEI	114	75	100	80	0.342	0.800	0.565	0.729
MEM	175	83	125	85	0.526	0.680	0.388	0.577
MGM	94	66	115	76	0.298	0.661	0.516	0.681
MIA	20	3	24	4	0.850	0.167	0.086	0.158
MOB	81	29	57	33	0.642	0.579	0.284	0.468
NEW	83	18	35	17	0.783	0.486	0.176	0.351
OKC	796	570	708	612	0.284	0.864	0.644	0.790
PBI	14	1	9	1	0.929	0.111	0.045	0.091
PNS	58	37	72	42	0.362	0.583	0.438	0.611
ROW	14	5	29	22	0.643	0.759	0.321	0.558
SAT	92	24	42	25	0.739	0.595	0.222	0.428

SAV	61	20	45	23	0.672	0.511	0.250	0.419
SHV	481	271	388	326	0.437	0.840	0.509	0.702
SJT	76	18	42	20	0.763	0.476	0.188	0.357
SPS	120	46	93	70	0.617	0.753	0.340	0.568
TBW	82	18	63	17	0.780	0.279	0.138	0.245
TLH	12	4	18	4	0.667	0.222	0.154	0.278
TRI	7	3	19	3	0.571	0.158	0.130	0.293
TUL	204	178	226	197	0.127	0.872	0.773	0.872
TUP	69	30	61	34	0.565	0.557	0.323	0.496
TYS	7	1	10	1	0.857	0.100	0.063	0.121
VCT	22	0	3	0	1.000	0.000	0.000	0.000
AYS	...NO SEVERE ACTIVITY...							
CKL	...NO SEVERE ACTIVITY...							
GGG	...NO SEVERE ACTIVITY...							
HDO	...NO SEVERE ACTIVITY...							
MLB	...NO SEVERE ACTIVITY...							
SEP	...NO SEVERE ACTIVITY...							
SIL	...NO SEVERE ACTIVITY...							

WESTERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	FAR	POD	CSI	VE
BIL	26	3	15	4	0.885	0.267	0.088	0.191
BOI	33	3	16	4	0.909	0.250	0.071	0.170
EKO	0	0	1	0	0.000	0.000	0.000	0.000
EUG	1	0	3	0	1.000	0.000	0.000	0.000
FAT	0	0	1	0	0.000	0.000	0.000	0.000
FCA	2	0	8	0	1.000	0.000	0.000	0.000
GEG	0	0	5	0	0.000	0.000	0.000	0.000
GGW	8	5	15	4	0.375	0.267	0.230	0.446
GTF	17	7	21	6	0.588	0.286	0.203	0.349
HLN	13	3	15	4	0.769	0.267	0.141	0.249
HVR	2	0	4	0	1.000	0.000	0.000	0.000
INW	0	0	1	0	0.000	0.000	0.000	0.000
LAS	6	1	6	1	0.833	0.167	0.091	0.167
LAX	9	5	4	3	0.444	0.750	0.469	0.653
MFR	1	0	1	0	1.000	0.000	0.000	0.000
MSO	13	1	11	2	0.923	0.182	0.057	0.000
PDX	0	0	2	0	0.000	0.000	0.000	0.000
PHX	15	6	13	6	0.600	0.462	0.273	0.431
PIH	18	2	25	2	0.889	0.080	0.049	0.095
RDD	6	1	2	1	0.833	0.500	0.143	0.333
RNO	7	0	5	0	1.000	0.000	0.000	0.000
SAC	15	1	1	0	0.933	0.000	0.000	0.033
SAN	0	0	3	1	0.000	0.333	0.333	0.333
SEA	0	0	2	0	0.000	0.000	0.000	0.000
SFO	1	1	2	2	0.000	1.000	1.000	1.000
SLC	17	2	20	2	0.882	0.100	0.057	0.109
TUS	8	3	10	3	0.625	0.300	0.200	0.338
YKM	0	0	4	0	0.000	0.000	0.000	0.000

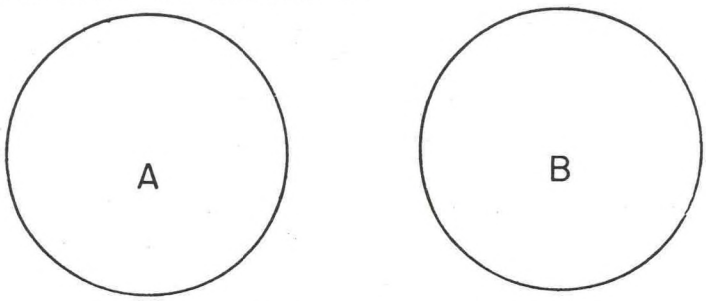
```
YUM     4     2      2       2    0.500  1.000   0.500  0.750
AST     ...NO SEVERE ACTIVITY...
BFL     ...NO SEVERE ACTIVITY...
BIH     ...NO SEVERE ACTIVITY...
EKA     ...NO SEVERE ACTIVITY...
ELY     ...NO SEVERE ACTIVITY...
FLG     ...NO SEVERE ACTIVITY...
LMT     ...NO SEVERE ACTIVITY...
LWS     ...NO SEVERE ACTIVITY...
MFR     ...NO SEVERE ACTIVITY...
OLM     ...NO SEVERE ACTIVITY...
PDX     ...NO SEVERE ACTIVITY...
SMX     ...NO SEVERE ACTIVITY...
WMC     ...NO SEVERE ACTIVITY...
```

Appendix B

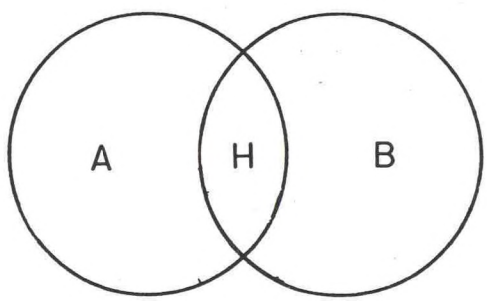
A Graphical Representation of the Critical Success Index

One of the various statistics used to summarize severe local storm warning verification is the Critical Success Index (CSI). The CSI, as defined in Section 2 of this report, is the ratio of successful predictions to the sum of the number of events and false alarms. A graphical representation of this index is helpful in clarifying its meaning and depicting its relationship to the Probability of Detection (POD) and False Alarm Ratio (FAR). Such a graphical illustration has been previously presented for precipitation forecasts (Charba and Klein, 1980).

First, let the number of county warnings issued be represented by the area in circle A. Let the number of severe local storm events be represented by the area of circle B.



Then, the intersection of these two areas, H, represents the number of verified county warnings, or successful predictions. A warning is verified when at least one severe local storm event occurs within the warned county. The area (A-H) represents the number of county warnings that did not verify, or the number of false alarms.



Expressing the definition of the CSI (given above) in terms of the areas in the figures gives

$$CSI = \frac{H}{(A-H)+B} \qquad (1B)$$

This expression can be rewritten as

$$CSI = [(B+(A-H))/H]^{-1}$$

$$= [(B/H) + (A/H)-1]^{-1} \quad (2B)$$

With some further manipulation,

$$CSI = [(H/B)^{-1} + (1-(A-H)/A)^{-1} -1]^{-1} \quad (3B)$$

If neither A nor B is zero, H/B is equivalent to the POD, and (A-H)/A is equivalent to the FAR.

Substitution into 3B then gives

$$CSI = [(POD)^{-1} + (1-FAR)^{-1} -1]^{-1} \quad (4B)$$

Thus, the CSI reflects both the POD and the FAR.

No. 8 A Minimum Assumption Tornado Hazard Probability Model. Joseph T. Schaefer, Donald L. Kelly, and Robert F. Abbey, May 1985, 30 p., (PB85 20692/AS).

No. 9 Verification of Severe Local Storm Forecasts Issued by the National Severe Storms Forecast Center: 1984. Preston W. Leftwich, Jr., November 1985, 23 p., (PB86 128105/AS).

No. 10 Severe Local Storm Warning Verification: 1984. Preston W. Leftwich, Jr. and Leo A. Grenier, December 1985, 14 p., (PB86 148244).

No. 11 Severe Thunderstorm Cases of 1985. John E. Hales, Jr. and Hugh G. Crowther, February 1986, 51 p., (PB86 164340/AS).

No. 12 Severe Local Storm Warning Verification Preliminary Procedures. Leo A. Grenier and John T. Halmstad, April 1986, 16 p., (PB86 194362).

No. 13 Verification of Severe Local Storm Forecasts Issued by the National Severe Storms Forecast Center: 1985. Preston W. Leftwich, Jr., November 1986, 9 p., (PB87 137139/AS).

No. 14 Severe Local Storm Warning Verification: 1985. Preston W. Leftwich, Jr. and Leo A. Grenier, December 1986, 16 p., (PB87 137147/AS).

No. 15 An Examination of the National Weather Service Severe Local Storm Warning Program and Proposed Improvements. John E. Hales, Jr., January 1987, 32 p., (PB87 147948/AS).

No. 16 Severe Thunderstorm Cases of July 1985 through June 1986. John E. Hales, Jr. and Hugh G. Crowther, February 1987, 72 p., (PB87 163911/AS).

No. 17 Severe Local Storm Warning Verification: 1986. Leo A. Grenier, John T. Halmstad and Preston W. Leftwich, Jr., June 1987, 19 p., (PB87 195939).

No. 18 Verification of Severe Local Storm Forecasts Issued by the National Severe Storms Forecast Center: 1986. Preston W. Leftwich, Jr., September 1987, 9 p., (PB88 101407).

No. 19 Severe Thunderstorm Cases of July 1986 through June 1987. John E. Hales, Jr. and Hugh G. Crowther, April 1988, 83 p., (PB88 214085).

*U.S. Government Printing Office:1990-757-139/20018

No. 20 Severe Local Storm Warning Verification: 1987. Leo A. Grenier, John T. Halmstad and Preston W. Leftwich, Jr., June 1988, 19 p., (PB88 241393).

No. 21 Verification of Severe Local Storm Forecasts Issued by the National Severe Storms Forecast Center: 1987. Preston W. Leftwich, Jr., December 1988, 11 p., (PB89 159719/AS).

No. 22 Severe Thunderstorm Cases of July 1987 thru June 1988. John E. Hales, Jr. and Hugh G. Crowther, April 1989, 92 p., (PB89 206411/AS)

No. 23 Severe Local Storm Warning Verification: 1988. Leo A. Grenier, John T. Halmstad and Preston W. Leftwich, Jr., June 1989, 26 p., (PB89 226310/AS).

No. 24 Verification of Severe Local Storm Forecasts Issued by the National Severe Storms Forecast Center: 1988. Preston W. Leftwich, Jr., September 1989, 18 p., (PB90-140211).

No. 25 A Dyad of Papers Concerning Joint Verification of Severe Local Storm Watches and Warnings During Tornado Events: Preston W. Leftwich, Jr. and John E. Hales, Jr., January 1990, 36 p.

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