NOAA TECHNICAL MEMORANDUM NWS NSSFC-17

SEVERE LOCAL STORM WARNING VERIFICATION: 1986

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

June 1987

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

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National Weather Service
National Severe Storms Forecast Center

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TABLE OF CONTENTS

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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 1986.

Stations in the Central and Southern regions again issued most of the warnings and experienced most of the severe local storm events. On a national scale, verification scores continued the trend of improvement of the past three years.

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 and their areas of responsibility are contained in Operations of the National Weather Service (NWS, 1985). 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 1986. 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 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). 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 telephone conversations or newspaper articles. These reports form a "rough log" of severe local storm events.

Each week, listings of warnings and event reports that have been logged and processed at the NSSFC are transmitted via the AFOS system to local offices for review. Roles of these warning and event summaries in the verification process are discussed in detail by Leftwich and Lee (1984), and updated in Grenier and Halmstad (1986). After reviewing these summaries, local offices send any corrections to the "rough log" to the Verification Specialist at the NSSFC. Additionally, "Storm Data and Unusual Weather Phenomena" (Form F-8) reports are reviewed as a final source of event data. In fact, these F-8 reports are the sole source of tornado reports used for official verification. After all forms of information have been compiled, the resulting "smooth log" and warning file provide 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). Multiple reports of any type 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 thunderstorm.

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.

A detailed examination and comparison of ALL severe local storm events versus "SIGNIFICANT" severe local storm events may be found in Hales (1987). "Significant" severe local storm events are identified using the criteria defined in Table 2. Because of the interest in, and demand for, significant event statistics, significant severe local storm events are identified on the 1986 final verification summary. Henceforth, significant event statistics will also be provided on all monthly summaries.

Table 2
Criteria for
"SIGNIFICANT" Severe Local Storm Events

a. Tornado - F2 or greater intensity on FPP scale.

b. Wind gusts - 65 knots or greater.

c. Hail - 2 inches in diameter or greater.

d. Wind damage - $50,000 damage or greater. (Non-agricultural)

e. All events resulting in 1 or more deaths, or 3 or more injuries.

Even though a severe local storm may occur in a particular county, sparseness of population may 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. Results of these studies demand that caution be exercised in directly comparing verification results for local offices, and even regions, that have different population densities or different meteorological regimes.

Once data have been compiled, various verification statistics are computed. Primary statistics are the Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) that were adapted from those described by Donaldson et al. (1975). Adaptations were necessary because the statistics described by Donaldson et al. considered point forecasts, but warnings are area forecasts.

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, one warning can cover many events. Any type of severe local storm event (Table 1) can verify either type (tornado or severe thunderstorm) warning. The POD, which is a measure of the correctness of the warnings in time and space, is computed as follows:

$$POD = \frac{\text{number of warned events}}{\text{total number of events.}} \qquad (1)$$

In current verification procedures, 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 values, the FAR is computed (as a measure of overwarning) as follows:

$$FAR = 1 - \frac{\text{number of verified counties}}{\text{number of warned counties.}} \qquad (2)$$

These two statistics are combined to form the CSI as follows:

$$CSI = [(POD)^{-1} + (1-FAR)^{-1} - 1]^{-1}. \quad (3)$$

For the CSI, higher values represent better skill, with a maximum possible value of "1". When either the FAR is "1" or the POD is "0", the CSI is undefined. The CSI, which is the same as the Threat Score, is the ratio of successful predictions to the number of events and false alarms. A graphical explanation of the CSI is given in Appendix B.

The Significant Probability of Detection (PODS) is calculated in exactly the same way as the POD. However, only those events that meet the "significant" criteria in Table 2 are used.

$$PODS = \frac{\text{number of warned significant events}}{\text{total number of significant events}}$$

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

$$PV = \frac{\text{number of verified counties}}{\text{number of warned counties}} \times 100 \quad (4)$$

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

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

and ranges from "0" to "1".

3. NATIONAL STATISTICS

Table 3 summarizes warning verification data for the entire United States during 1986. A total of 10,789 counties were warned via warning messages, and 8,725 severe local storm events were reported. Nationwide, approximately 59% of these events occurred in warned counties, and at least one severe local storm event was observed in 39% of the warned counties. The resulting national CSI was 0.30 and the VE was 0.49. Significant events comprised 8.5% of the total number of severe local storm events, and 51% of the significant events occurred in warned counties.

Table 3
National Severe Local Storm Warning
Verification Data: 1986

Counties Warned	10,789
County Warnings Verified	4,155
Severe Local Storm Events	8,725
Warned Events	5,118
FAR	.61
POD	.59
CSI	.30
% Verified	39
VE	.49
Significant Event Data	
Severe Local Storm Events	743
Warned Events	378
PODS	.51

Figures 1a, b and c show the distributions of some of these station statistics. Only those stations that issued at least one warning were included in the raw distribution. Because stations with minimal activity tend to fall into the extremes of the raw distribution, the data has been "smoothed" 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).

A comparison of the raw distribution to the smooth distribution is shown in Figures 1a, b and c. Median values are also shown for both distributions of the FAR, POD and CSI, respectively.

Figure 2 depicts the trend in national statistics for the past six years. The upward trend in the POD appears to have slowed during the past two years but improvement continues.

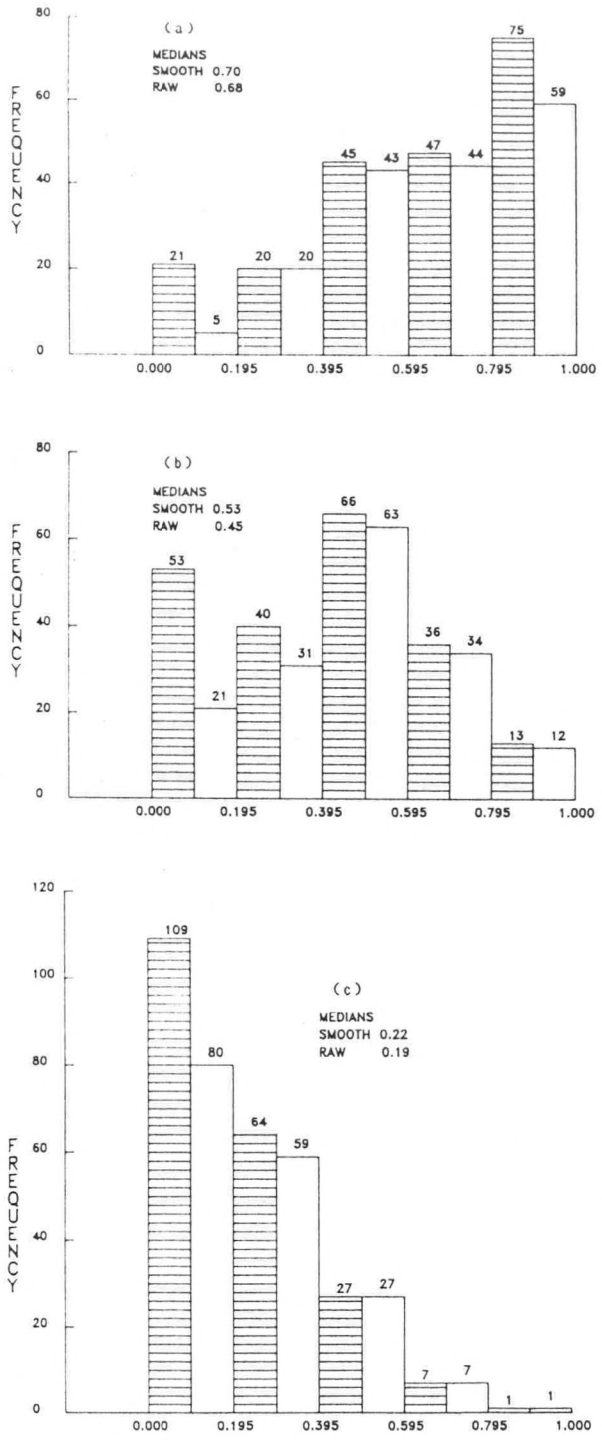

Figure 1. Frequency distributions of severe local storm warning verification statistics for 1986 (a) FAR (b) POD, and (c) CSI.

Raw Distribution = Hatched Bar
Smooth Distribution = Open Bar

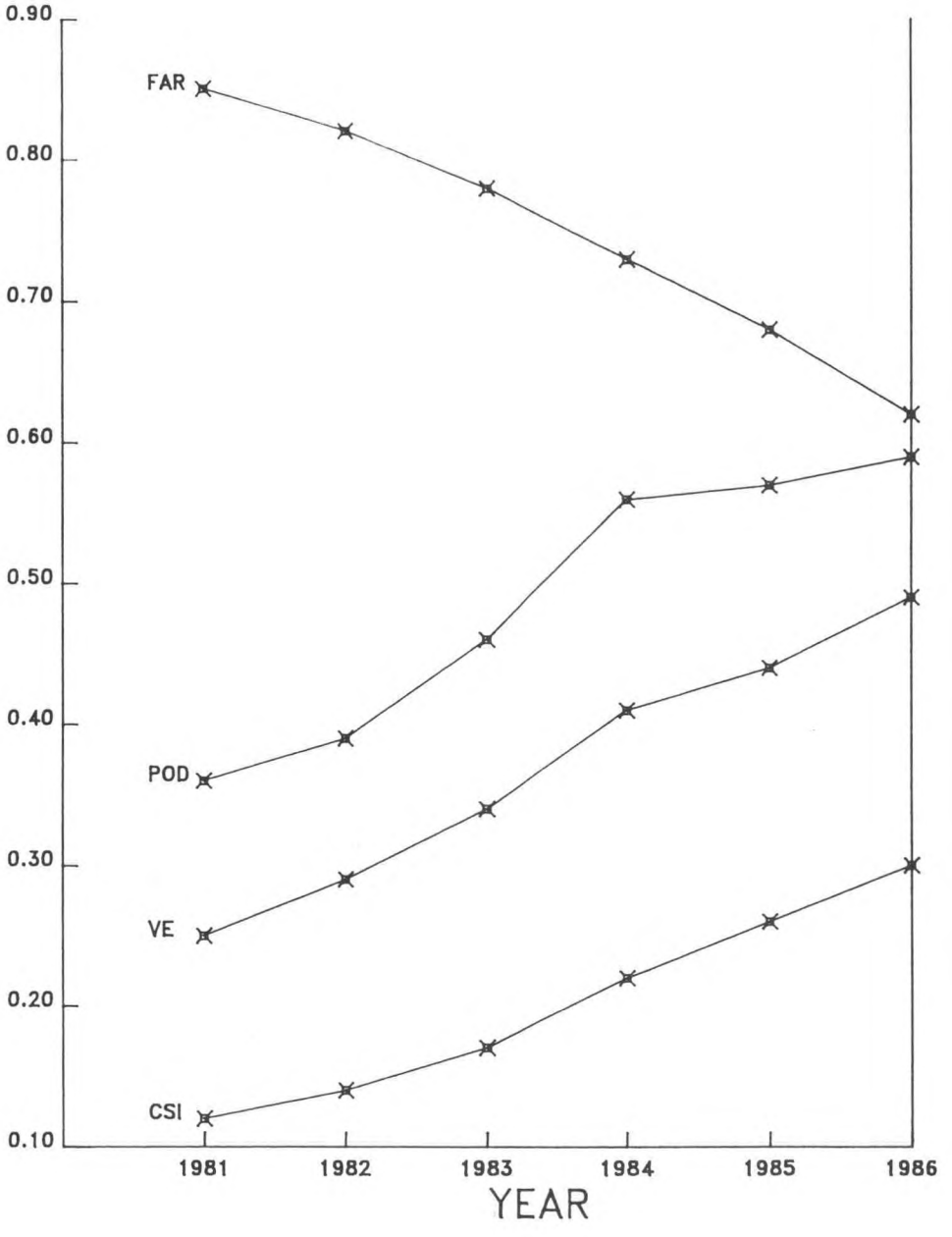

Figure 2. National severe local storm warning verification statistics for the years 1981-1986.

During 1986, 764 tornadoes caused 15 fatalities and 536 injuries in the United States. This is the lowest annual fatality count since 1916, when recordkeeping of this statistic began. In addition, it is nearly 40 percent less than the previous low record of 24 in 1981. As shown in Table 4, 67 percent of all tornado fatalities and 61 percent of all tornado injuries, occurred within a valid severe local storm warning. Severe thunderstorm wind gusts caused another 36 fatalities and 379 injuries. Of these, 31 percent of the fatalities and 40 percent of the injuries occurred within a warned area.

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

	Tornado		Severe Thunderstorm	
	Fatalities	Injuries	Fatalities	Injuries
Total Number	15	536	36	379
Within Valid Warnings	10	327	11	153
% Within Warnings	67	61	31	40

Figure 3 shows the number of annual reports received in three categories for a 32 year period. While the number of tornadoes has remained relatively steady, the number of wind/hail reports and the total events have been increasing. Since the start of the National Weather Service Verification Program in 1982, a faster rate of increase in total events is evident. In an effort to eliminate duplicate reports, which had previously been retained, the definition of an event was changed in Leftwich and Lee (1984). Between 11,000 and 14,000 raw events have been received each year from 1984 through 1986. Approximately 30 to 40 percent of these have been discarded as duplicates. If the current trend in annual report totals continues, automation of this process appears to be the only alternative for handling the data.

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). 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 1986. For example, the Southern region issued 39.0% of the county warnings during 1986. This region also had 41.2% of the verified counties, 40.0% of the severe events and 42.9% of the warned events. Also note that nearly one-half of the significant events in 1986 occurred in the Central Region.

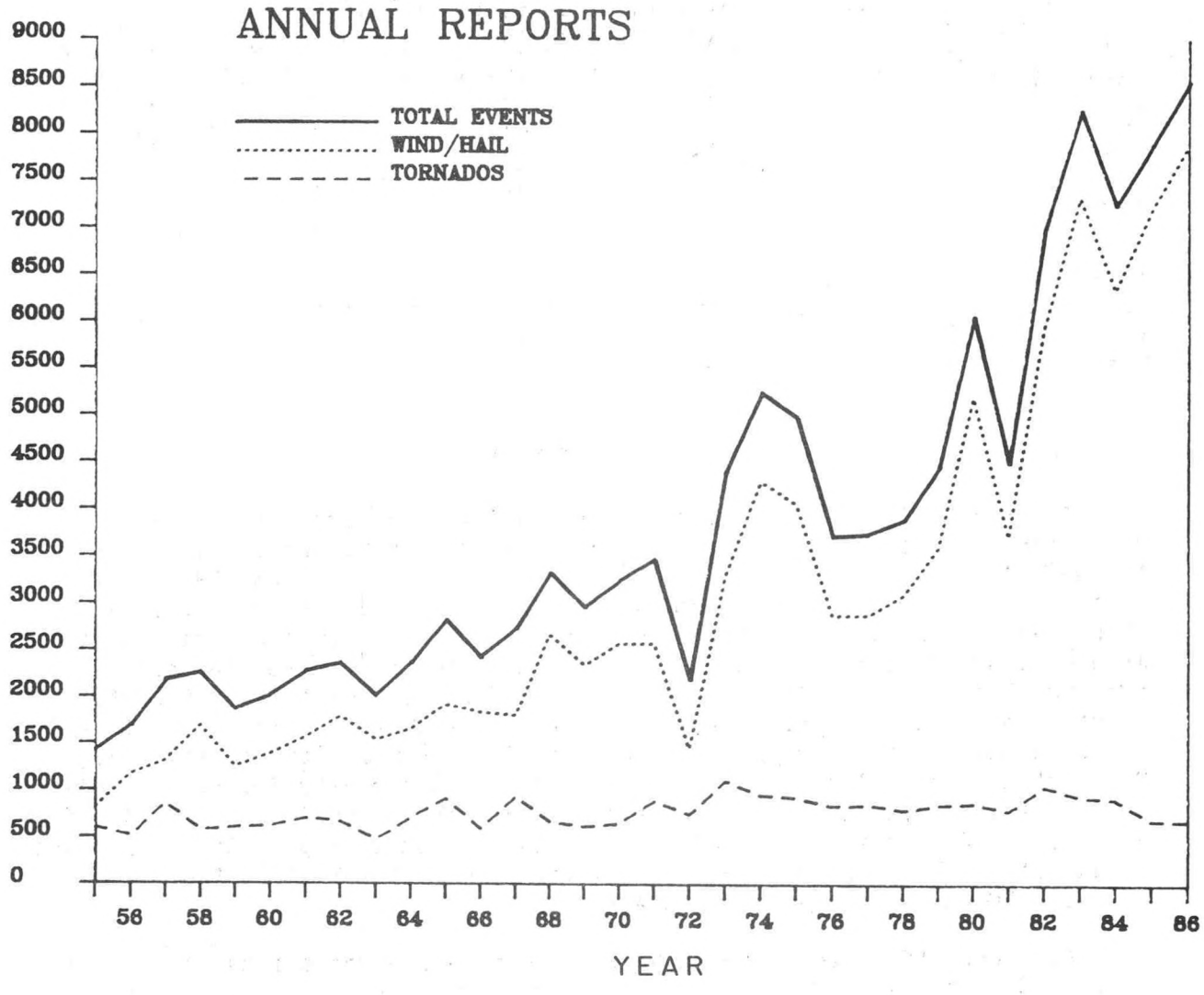

Figure 3. Annual totals of event reports 1955-1986.

Table 5

Regional Severe Local Storm Warning Verification Data: 1986
Numbers in parentheses are percentages of national totals for each item.

	Eastern	Central	Southern	Western
Counties Warned	1445 (13.4)	4868 (45.1)	4212 (39.0)	264 (2.5)
County Warnings Verified	793 (19.1)	1623 (39.1)	1715 (41.2)	24 (0.6)
Severe Local Storm Events	1627 (18.7)	3427 (39.3)	3494 (40.0)	177 (2.0)
Warned Events	952 (18.5)	1948 (38.1)	2195 (43.0)	23 (0.4)
FAR	.45	.67	.59	.91
POD	.59	.57	.63	.13
CSI	.40	.27	.33	.06
% Verified	55	33	41	9
VE	.57	.45	.52	.11
Significant Event Data				
Severe Local Storm Events	96 (12.9)	369 (49.7)	267 (35.9)	11 (1.5)
Warned Events	39	215	123	1
PODS	.41	.58	.46	.09

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 1986. 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 (e.g., FLG in the Western Region) having a POD greater than zero in Appendix A.

From one office to another there are often wide variations in numbers such as warnings issued and severe local storm events. 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 made among verification results from the various offices.

6. SUMMARY

All 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 1986.

Although the period of record is only six years, verification statistics have shown trends of improvement. 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. Such factors demand caution in direct comparisons of verification statistics among regions or local offices.

7. ACKNOWLEDGMENTS

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Appendix A

Severe Local Storm Warning Verification for NWS Offices: 1986

* * * 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
SIG EVNTS = SIGNIFICANT EVENTS
FAR = FALSE ALARM RATIO
POD = PROBABILITY OF DETECTION
PODS = PROBABILITY OF DETECTION (SIGNIFICANT EVENTS ONLY)
CSI = CRITICAL SUCCESS INDEX
VE = VERIFICATION EFFICIENCY

EASTERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	SIG EVNTS	FAR	POD	PODS	CSI	VE
ABE	7	7	10	7	0	.000	.700	---	.700	.850
ACY	7	6	8	7	1	.143	.875	.000	.764	.866
ALB	72	41	107	56	4	.431	.523	.250	.375	.546
AVL	4	4	16	5	1	.000	.313	.000	.313	.656
AVP	1	1	3	1	1	.000	.333	.000	.333	.666
BDL	2	1	3	1	0	.500	.333	.---	.250	.416
BGM	14	10	31	14	2	.286	.452	.500	.383	.583
BKW	7	1	3	1	0	.857	.333	.---	.111	.238
BOS	23	2	12	2	2	.913	.167	.000	.061	.127
BTV	55	30	52	32	0	.455	.615	.---	.407	.580
BUF	45	19	32	20	0	.578	.625	.---	.337	.524
BWI	18	7	22	6	3	.611	.273	.333	.191	.331
CAE	48	27	56	30	0	.438	.536	.---	.378	.549
CAK	38	22	40	26	0	.421	.650	.---	.441	.614
CAR	2	2	7	7	0	.000	1.000	.---	1.000	1.000
CHS	26	5	19	5	0	.808	.263	.---	.125	.228
CLE	53	30	41	30	2	.434	.732	1.000	.469	.649
CLT	24	12	39	20	1	.500	.513	1.000	.339	.506
CMH	46	28	42	26	11	.391	.619	.727	.443	.614

CON	30	17	50	29	4	.433	.580	.250	.402	.573
CRW	16	7	16	7	2	.562	.437	.000	.280	.438
CVG	33	10	36	10	5	.697	.278	.400	.169	.290
DAY	57	36	62	38	6	.368	.613	.500	.451	.622
EKN	30	19	29	23	0	.367	.793	.---	.544	.713
ERI	45	29	53	36	1	.356	.679	1.000	.494	.662
GSO	25	15	37	14	1	.400	.378	.000	.302	.489
GSP	35	15	37	16	1	.571	.432	.000	.274	.431
HAR	23	20	40	23	3	.130	.575	.333	.529	.722
HAT	61	20	40	24	3	.672	.600	.333	.269	.464
HTS	9	7	20	11	0	.222	.550	.---	.475	.664
ILG	6	2	3	2	0	.667	.667	.---	.286	.500
ILM	92	48	97	60	6	.478	.619	.500	.395	.570
IPT	6	3	8	5	0	.500	.625	.---	.385	.563
MFD	12	4	13	7	2	.667	.538	1.000	.259	.436
NYC	9	1	6	1	0	.889	.167	.---	.071	.138
ORF	12	9	24	13	3	.250	.542	.333	.459	.646
ORH	3	1	3	1	0	.667	.333	.---	.200	.333
PHL	8	5	8	5	0	.375	.625	.---	.455	.625
PIT	116	59	99	81	2	.491	.818	.000	.457	.663
PVD	11	2	4	2	3	.818	.500	.333	.154	.341
PWM	34	28	57	43	4	.176	.754	.500	.649	.789
RDU	112	85	163	103	7	.241	.632	.429	.526	.695
RIC	18	1	22	1	5	.944	.045	.000	.026	.050
ROA	2	1	4	2	0	.500	.500	.---	.333	.500
ROC	13	9	15	8	0	.308	.533	.---	.431	.613
SYR	45	35	55	48	3	.222	.873	.667	.699	.825
TOL	56	35	41	28	3	.375	.683	.667	.484	.654
WBC	6	2	16	2	2	.667	.125	.500	.100	.229
YNG	28	13	26	13	2	.536	.500	.000	.317	.482

CENTRAL REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	SIG EVNTS	FAR	POD	PODS	CSI	VE
ABR	100	20	46	21	8	.800	.457	.750	.162	.328
ALO	15	5	23	5	1	.667	.217	.000	.152	.275
ALS	0	0	3	0	0	.000	.000	.---	.000	.000
APN	6	0	1	0	0	1.000	.000	.---	.000	.000
BFF	84	13	34	15	1	.845	.441	1.000	.129	.298
BIS	120	59	102	68	20	.508	.667	.600	.395	.579
CHI	30	7	26	7	9	.767	.269	.222	.143	.251
CNK	203	126	192	166	14	.379	.865	.714	.566	.743
COS	67	11	28	13	3	.836	.464	.333	.138	.314
COU	52	22	29	24	3	.577	.828	.667	.389	.625
CPR	29	2	9	2	2	.931	.222	.500	.056	.146
CYS	55	25	51	34	11	.545	.667	.455	.370	.560
DBQ	9	3	13	3	0	.667	.231	.---	.158	.282
DDC	105	82	114	95	7	.219	.833	1.000	.675	.807

DEN	122	24	80	29	8	.803	.363	.125	.146	.280
DLH	76	14	30	14	2	.816	.467	.500	.152	.325
DSM	221	89	233	121	18	.597	.519	.611	.293	.461
DTW	73	29	57	34	1	.603	.596	1.000	.313	.497
EVV	48	29	50	31	4	.396	.620	.750	.441	.612
FAR	110	30	85	41	10	.727	.482	.600	.211	.378
FNT	44	11	22	12	3	.750	.545	1.000	.207	.398
FSD	337	59	125	72	34	.825	.576	.676	.155	.376
FWA	48	22	61	33	1	.542	.541	1.000	.330	.500
GJT	0	0	2	0	0	.000	.000	.---	.000	.000
GLD	86	65	101	78	10	.244	.772	.400	.618	.768
GRB	23	3	14	3	2	.870	.214	.000	.088	.172
GRI	246	65	130	69	17	.736	.531	.706	.214	.397
GRR	29	15	29	15	3	.483	.517	.667	.349	.517
HON	125	28	55	31	16	.776	.564	.750	.191	.394
HTL	5	1	3	2	0	.800	.667	.---	.182	.433
ICT	186	69	111	83	17	.629	.748	.647	.330	.559
IND	176	92	159	108	12	.477	.679	1.000	.419	.601
INL	7	3	2	2	0	.571	1.000	.---	.429	.714
ISN	37	11	19	14	0	.703	.737	.---	.269	.517
JKL	14	5	15	5	0	.643	.333	.---	.208	.345
LAN	54	16	32	17	5	.704	.531	.400	.235	.414
LBF	95	17	48	17	7	.821	.354	.714	.135	.267
LEX	18	8	31	9	1	.556	.290	.000	.213	.367
LND	4	1	8	2	1	.750	.250	.000	.143	.250
LNK	34	8	37	8	4	.765	.216	.250	.127	.226
LSE	22	3	10	4	1	.864	.400	1.000	.113	.268
MCI	45	26	55	32	3	.422	.582	1.000	.408	.580
MKE	84	13	53	12	4	.845	.226	.500	.101	.191
MKG	19	6	10	8	0	.684	.800	.---	.293	.558
MLI	22	6	23	7	1	.727	.304	1.000	.168	.289
MQT	45	7	10	7	1	.844	.700	1.000	.146	.428
MSN	71	9	22	8	1	.873	.364	.000	.104	.245
MSP	206	55	111	66	13	.733	.595	.385	.226	.431
OFK	126	40	85	44	18	.683	.518	.444	.245	.418
OMA	92	28	73	33	12	.696	.452	.667	.222	.378
PAH	92	23	45	24	5	.750	.533	.800	.205	.392
PIA	37	9	23	10	3	.757	.435	.333	.185	.339
PUB	53	4	14	4	0	.925	.286	.---	.063	.181
RAP	62	12	40	12	7	.806	.300	.429	.133	.247
RFD	19	6	15	5	0	.684	.333	.---	.194	.325
RST	52	7	33	9	1	.865	.273	.000	.099	.204
SBN	24	12	27	15	2	.500	.556	.500	.357	.528
SDF	104	32	95	40	4	.692	.421	.500	.216	.364
SGF	83	40	68	55	4	.518	.809	.750	.433	.645
SHR	12	4	21	4	6	.667	.190	.333	.138	.262
SPI	118	32	75	43	4	.729	.573	1.000	.226	.422
SSM	15	0	0	0	0	1.000	.000	.---	.000	.000
STC	77	11	21	12	1	.857	.571	1.000	.129	.357
STL	109	48	95	56	7	.560	.589	.714	.337	.515
SUX	46	31	65	45	8	.326	.692	1.000	.519	.683
TOP	125	67	121	86	12	.464	.711	.917	.440	.623
VTN	15	3	7	4	1	.800	.571	.000	.174	.386

SOUTHERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	SIG EVNTS	FAR	POD	PODS	CSI	VE
ABI	179	46	74	54	10	.743	.730	1.000	.235	.493
ABQ	17	3	5	1	0	.824	.200	.---	.103	.188
ACT	37	13	25	14	3	.649	.560	.667	.275	.456
AGS	22	0	16	0	0	1.000	.000	.---	.000	.000
AHN	60	32	57	35	2	.467	.614	.000	.399	.574
AMA	61	16	62	17	11	.738	.274	.455	.155	.268
AQQ	6	0	2	0	0	1.000	.000	.---	.000	.000
ATL	39	27	63	29	2	.308	.460	.000	.382	.576
AUS	50	5	20	9	2	.900	.450	1.000	.089	.275
BHM	143	41	94	48	6	.713	.511	.833	.225	.399
BNA	33	2	22	2	4	.939	.091	.000	.038	.076
BPT	56	9	21	11	5	.839	.524	.200	.140	.342
BRO	36	7	14	8	1	.806	.571	1.000	.170	.383
BTR	19	1	10	2	0	.947	.200	.---	.043	.126
CAO	0	0	1	0	0	.000	.000	.---	.000	.000
CHA	20	9	17	10	4	.550	.588	.500	.342	.519
CRP	39	9	24	11	1	.769	.458	.000	.181	.345
CSG	26	7	20	8	0	.731	.400	.---	.192	.335
DAB	23	3	16	3	1	.870	.187	.000	.083	.159
DRT	6	1	4	1	0	.833	.250	.---	.111	.208
ELP	11	2	15	3	1	.818	.200	.000	.105	.191
ESF	1	0	3	1	0	1.000	.333	.---	.000	.167
EYW	2	2	0	0	0	.000	.000	.---	.000	.000
FMY	0	0	4	0	3	.000	.000	.000	.000	.000
FSM	111	46	83	58	3	.586	.699	.667	.352	.557
FTW	365	183	310	233	20	.499	.752	.850	.430	.626
GLS	24	7	12	8	1	.708	.667	1.000	.255	.479
HOU	64	27	57	32	7	.578	.561	.429	.317	.492
HSV	77	22	51	27	2	.714	.529	.500	.228	.408
JAN	88	47	101	55	20	.466	.545	.250	.369	.539
JAX	32	14	43	19	2	.562	.442	.500	.282	.440
LBB	114	46	81	51	10	.596	.630	.700	.326	.517
LCH	23	2	5	1	1	.913	.200	.000	.065	.143
LIT	181	61	142	76	7	.663	.535	.571	.261	.436
MAF	142	20	45	25	3	.859	.556	.667	.127	.348
MCN	35	22	39	24	1	.371	.615	.000	.451	.622
MCO	10	2	11	2	1	.800	.182	.000	.105	.191
MEI	50	24	47	27	8	.520	.574	.750	.354	.527
MEM	96	24	73	32	5	.750	.438	.200	.189	.344
MGM	41	36	74	46	8	.122	.622	.750	.572	.750
MIA	47	5	33	9	1	.894	.273	.000	.083	.190
MOB	118	23	56	31	0	.805	.554	.---	.168	.374
NEW	49	2	16	3	1	.959	.187	.000	.035	.114
OKC	763	544	902	741	38	.287	.822	.684	.617	.767
PBI	10	1	9	1	2	.900	.111	.000	.056	.106
PNS	38	1	6	1	0	.974	.167	.---	.023	.096
ROW	4	0	6	3	0	1.000	.500	.---	.000	.250
SAT	62	12	42	17	8	.806	.405	.375	.151	.299

SAV	54	14	44	16	6	.741	.364	.167	.178	.311
SHV	301	149	230	196	23	.505	.852	.913	.456	.674
SJT	33	3	20	4	0	.909	.200	.---	.067	.145
SPS	152	65	117	86	12	.572	.735	.833	.371	.581
TBW	45	4	50	4	1	.911	.080	1.000	.044	.084
TLH	8	2	13	2	2	.750	.154	.000	.105	.202
TRI	5	0	0	0	0	1.000	.000	.---	.000	.000
TUL	114	47	129	74	14	.588	.574	.786	.316	.493
TUP	29	14	25	14	4	.517	.560	.000	.350	.521
TYS	10	1	22	1	0	.900	.045	.---	.032	.072
VCT	31	10	11	9	0	.677	.818	.---	.301	.570

WESTERN REGION

STN	WRND CNTYS	VERF CNTYS	TOT EVNTS	WRND EVNTS	SIG EVNTS	FAR	POD	PODS	CSI	VE
BIH	0	0	1	0	0	.000	.000	.---	.000	.000
BIL	60	4	16	4	3	.933	.250	.000	.056	.158
BOI	17	1	10	1	0	.941	.100	.---	.038	.079
EKA	0	0	2	0	0	.000	.000	.---	.000	.000
EKO	0	0	2	0	0	.000	.000	.---	.000	.000
ELY	2	0	1	0	0	1.000	.000	.---	.000	.000
EUG	0	0	1	0	0	.000	.000	.---	.000	.000
FAT	3	0	2	0	1	1.000	.000	.000	.000	.000
FLG	0	0	6	1	0	.000	.167	.---	.167	.167
GEG	1	0	1	0	0	1.000	.000	.---	.000	.000
GGW	17	0	1	0	0	1.000	.000	.---	.000	.000
GTF	18	1	5	1	0	.944	.200	.---	.045	.128
HLN	7	0	1	0	0	1.000	.000	.---	.000	.000
HVR	2	0	4	0	0	1.000	.000	.---	.000	.000
INW	0	0	2	0	0	.000	.000	.---	.000	.000
LAS	2	0	4	0	0	1.000	.000	.---	.000	.000
LAX	3	0	6	0	2	1.000	.000	.000	.000	.000
LWS	3	0	2	0	0	1.000	.000	.---	.000	.000
MFR	2	0	0	0	0	1.000	.000	.---	.000	.000
MSO	9	0	0	0	0	1.000	.000	.---	.000	.000
PDT	2	0	0	0	0	1.000	.000	.---	.000	.000
PDX	4	0	0	0	0	1.000	.000	.---	.000	.000
PHX	39	8	38	8	5	.795	.211	.000	.116	.208
PIH	14	2	13	2	1	.857	.154	1.000	.080	.148
RDD	7	0	4	0	1	1.000	.000	.000	.000	.000
RNO	3	1	2	1	0	.667	.500	.---	.250	.417
SAC	9	0	4	0	0	1.000	.000	.---	.000	.000
SEA	4	0	2	0	1	1.000	.000	.000	.000	.000
SFO	0	0	3	0	0	.000	.000	.---	.000	.000
SLC	28	4	29	3	0	.857	.103	.---	.064	.123
TUS	7	3	11	2	0	.571	.182	.---	.146	.305
YKM	1	0	0	0	0	1.000	.000	.---	.000	.000
YUM	0	0	4	0	0	.000	.000	.---	.000	.000

Appendix B

A Graphical Representation of the Critical Success Index

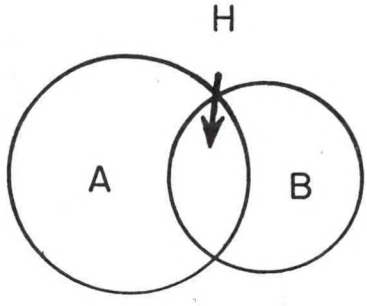
Various statistics used to summarize severe local storm warning verification were discussed in Section 2 of this report. Most of these statisitcs are defined by straightforward ratios. An exception is the Critical Success Index (CSI), as defined by

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

A graphical representation of the relationships contained in (1B) is often helpful in clarifying the meaning of a CSI, or Threat Score. 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, and let the number of severe local storm events be represented by the area of circle B.

Then, the intersection of these two areas, H, will represent the number of verified warnings, i.e., a warning was issued and at least one severe event occurred in the warned county. The area (A-H) represents the number of false alarms. Further, the FAR is depicted by the ratio (A-H)/A and the POD is depicted by the ratio H/B.



Substituting these values into (1B) gives the following:

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

then,

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

and

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

Thus, the CSI is the ratio of verified warnings to the sum of the false alarms and the number of severe events.

No. 8 A Minimum Assumption Tornado Hazard Probability Model. Donald L. Kelly, Joseph T. Schaefer, and Robert F. Abbey, Jr., May 1985, 30 p., (PB85 206092/AS).

No. 9 Verification of Severe Local Storm Forecasts Issued By The National Severe Storm 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, 10 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 thru June 1986. John E. Hales, Jr. and Hugh G. Crowther, February 1987, 72 p., (PB87 163911/AS).

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