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DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

VERIFICATION OF SEVERE LOCAL STORM WARNINGS BASED ON RADAR ECHO CHARACTERISTICS

Techniques Development Laboratory
Silver Spring, Md.
June 1976

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ABSTRACT. Severe local storm warnings are often released to the public based on radar echo characteristics. An attempt is made to verify these warnings with information contained in the manually-digitized radar reports and severe local storm climatology data. Results of the verification indicate that in the spring months there is some skill demonstrated in these warnings especially in areas close to radar sites. This skill decreases noticeably in the summer months and in areas more remote from radar sites.

INTRODUCTION

In a recent study of manually-digitized radar (MDR) data by Foster and Reap (1975), there was evidence that current radar criteria used as guidance for issuing severe local storm warnings to the public may result in too many false alarms. Current criteria used as a guide for issuing these warnings include the following radar echo characteristics.

Tornado Warnings:

a. Hook echoes (often accompanied by a V-notch on the downward side of the cell).

b. Rotating cell or cluster of cells.

c. Cell whose intensity is $10^{4.5}m^6/m^3$ or greater with a vault or echo free region.

Severe Thunderstorm Warnings:

a. Reflectivity of $10^{4.5}m^6/m^3$

b. Tops exceeding the ambient tropopause height by at least 5000 ft.

c. Tops equal to or greater than 50,000 ft. (Does not necessarily hold for summertime thunderstorms in the gulf coastal areas.)

d. Speed of movement equal to or greater than 40 kt (30 kt in gulf coastal states) in cells whose intensity is $10^5mm^6/m^3$.

e. Rapidly developing cells ($10^{4.5}mm^6/m^3$ in 30 minutes).

f. Merging or splitting cells, one of which is $10^{4.5}mm^6/m^3$ or greater.

g. Cells whose intensity is $10^{4.5}mm^6/m^3$ or greater and whose direction of movement changes abruptly to the right or left.

h. Cell at or near the crest of a LEWP (line echo wave pattern) whose intensity is $10^{4.5}mm^6/m^3$ or greater and whose speed of movement is equal to or greater than 35 kt.

i. Echo configuration including scalloped edges, V-notches, and/or hail shaft.

The additive data section of the MDR report provides for coding a plus sign (+) for an MDR block that contains an echo that meets any of the above criteria. A complete description of the MDR code is found in Moore, Cummings, and Smith (1974).

The purpose of this paper is to report on our latest efforts to evaluate severe local storm warnings for the spring and summer months of 1974 and the spring of 1975. In the evaluation we used statistical scores defined by Donaldson (1975) along with more familiar statistical scores such as bias and skill scores. These results should prove useful as a basis for comparison if new radar criteria for warning guidance are implemented.

DATA BASE

The data used in the evaluation consist of MDR and severe local storm data archived on magnetic tape by the Techniques Development Laboratory (Foster and Reap 1975). The MDR data contain both echo intensity and coverage, supplemented by additive data indicating severe convective cells and line echoes. MDR reports were recorded hourly about half past the hour for each MDR block shown in figure 1. The severe local storm data include reports of tornadoes, wind gusts $\geq$ 50 kt and/or wind damage, and surface hail $\geq$ 3/4 in. in diameter. The severe local storm reports archived for a particular MDR block were those occurring during the 1-hr period since the last MDR report. Only MDR blocks containing echoes of thunderstorm intensity, defined by MDR code values of 4 or greater, were used in this verification. Reference to table 1 shows that MDR code 4 indicates an echo that covers one half or less of an MDR block area with strong intensity. According to a study made by Mogil (1974), echoes defined by MDR code 4 or greater indicate thunderstorm activity while those of lesser codes are predominately rain showers.

VERIFICATION METHOD

The object of this evaluation is to identify all MDR blocks with thunderstorms and measure how well the application of the criteria listed in the introduction determines if a thunderstorm will be accompanied by a severe local storm as defined above.

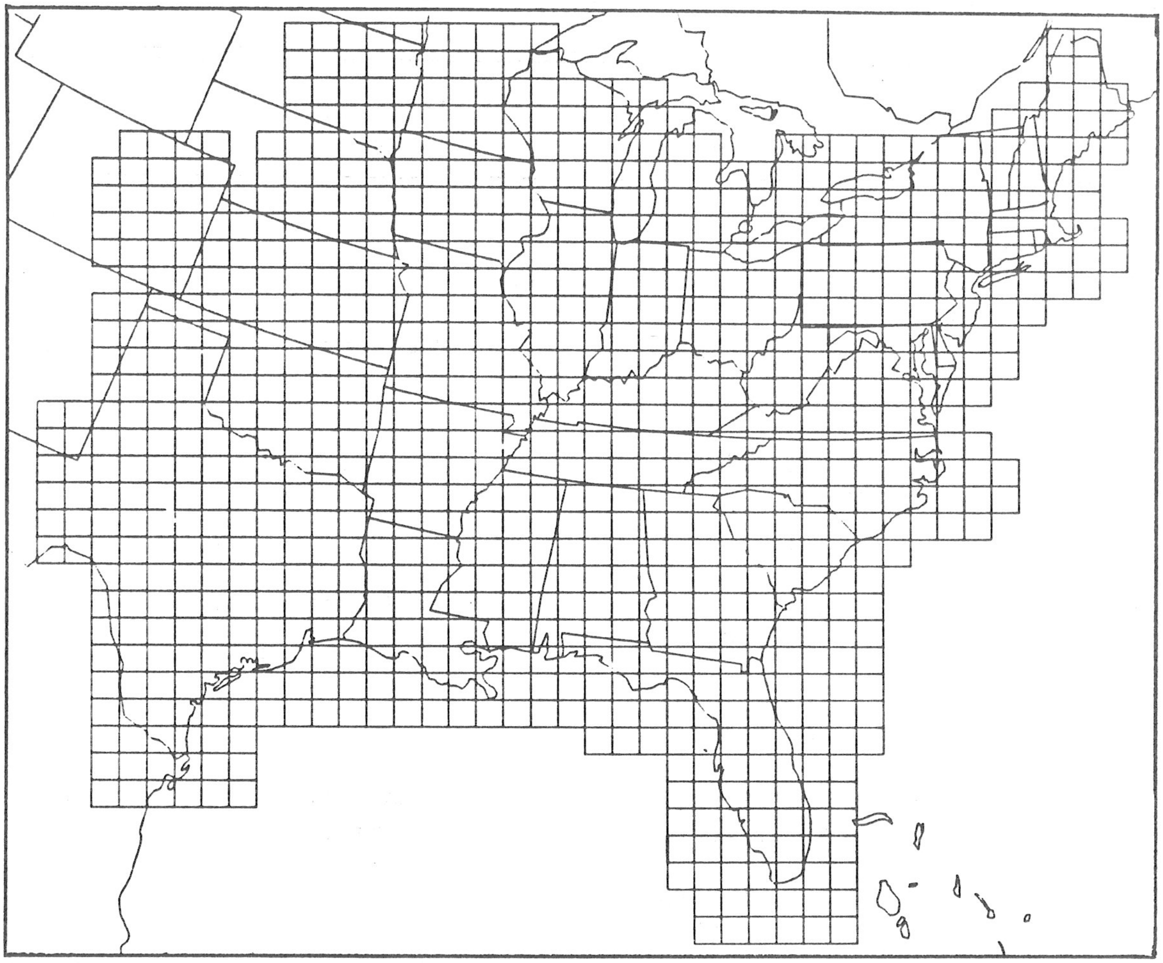


Figure 1.--MDR grid for which data were collected for verification.

Table 2 shows the contingency table used in computing the verification scores. A tabulation was made in the "predicted severe" category when an MDR block was coded with a plus sign in the additive data section of the MDR report; a tabulation was made in the "predicted no severe" category when an MDR block with a thunderstorm did not have a plus sign coded in the additive data section. A plus sign was interpreted to mean that an MDR thunderstorm echo met radar warning criteria and a local warning was issued for possible tornado or severe thunderstorm activity. In addition to radar echo characteristics, it is conceivable that a plus sign may be coded for an MDR block on the basis of a severe local storm report regardless of the signature of the radar echo. These cases would be tabulated as "severe predicted" and "severe observed." If verification scores were unusually high, this would be a suspected cause. However, since scores are unusually low, this is probably an infrequent practice. The time-lag associated with the reporting of severe local storms acts to keep the number of these cases low.

Table 1.--Manually-digitized radar (MDR) code compared with area coverage, video integrator and processor codes (VIP), intensity category, and rainfall rate.

Code Number	Coverage in box	Intensity category	Rainfall rate (in/hr)
0			
1	any VIP	Weak	< .1
2	$\leq$ 1/2 of VIP2	Moderate	.1 - .5
3	> 1/2 of VIP2		
4	$\leq$ 1/2 of VIP3	Strong	.5 - 1.0
5	> 1/2 of VIP3		
6	$\leq$ 1/2 of VIP3 and VIP4	Very Strong	1.0 - 2.0
7	> 1/2 of VIP3 and VIP4		
8	$\leq$ 1/2 of VIP3, 4, 5, and 6	Intense or Extreme	> 2.0
9	> 1/2 of VIP3, 4, 5, and 6		

Table 2.--Contingency table used in computing verification scores.

Observed	Predicted		
	Severe	No Severe	Total
Severe	X	Y	X + Y
No Severe	Z	W	Z + W
Total	X + Z	Y + W	X + Y + Z + W

The "observed severe" or "observed no severe" categories in table 2 are more difficult to determine. First we must note that a complete association between an MDR thunderstorm echo and an observed severe local storm is not possible due to the differences in scale between the echoes and the MDR reporting blocks, and the probable time differences between MDR reports and severe local storm reports. Therefore, to proceed with the verification some assumptions had to be made which we consider to be reasonable if not entirely accurate. For example, only hourly MDR reports are archived on tape; therefore, an MDR thunderstorm echo predicted severe by radar criteria (plus sign) in block A of figure 2 may have been so identified any time within the preceding hour. Because of the speed and direction of movement of thunderstorm echoes, such an echo may initially have been identified in a block adjacent to block A. In other cases an MDR thunderstorm echo may initially have been predicted severe in block A minutes before reporting time and moved into an adjacent block where a severe local storm may have occurred. In the latter cases the predicted severe thunderstorm in block A was allowed to be verified by severe local storms observed in adjacent blocks during the following hour. Figure 2 shows the search order followed in verifying an MDR thunderstorm predicted severe in block A. The search in figure 2a was performed first for observed severe local storms that occurred during the hour prior to the current MDR report. If no severe storm blocks were found, the search in figure 2b was performed for severe local storms observed during the hour after the current MDR report. This search order assumes thunderstorm movement from a southerly, westerly or northerly direction. Once a severe storm block was found, the search was discontinued except that if a severe local storm block was also coded with a plus sign, the block was passed over to await its own verification. If a block was selected in the first search, the block was cleared in the search array so that it could not be selected to verify any other block. If a block was found in the second search, it was left undisturbed to be used in verifying the next hour's warning code.

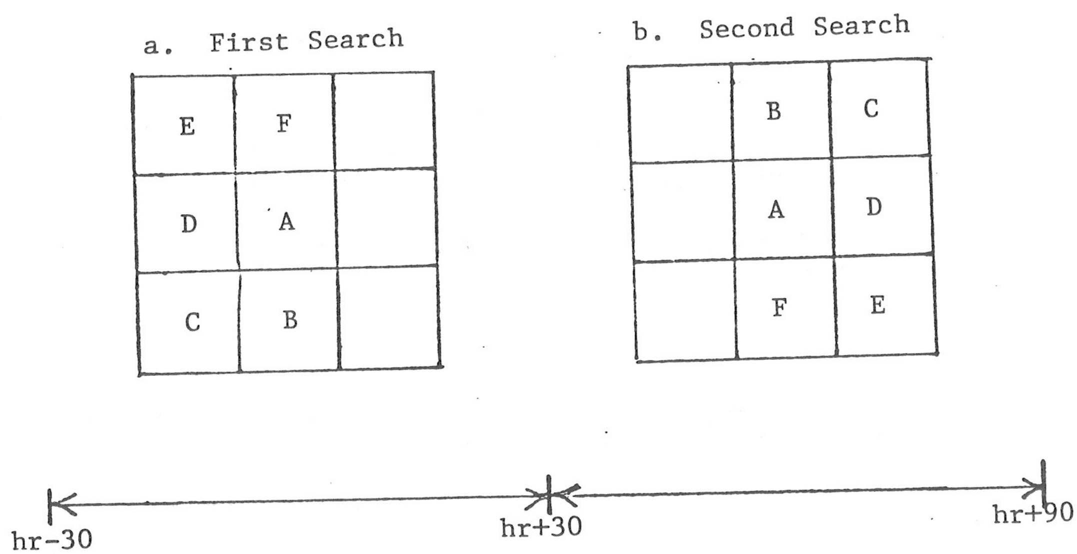


Figure 2.--Search order for determining whether a severe local storm was observed when an MDR thunderstorm echo met severe criteria in block A at hr + 30 minutes.

After all predicted severe blocks for 1 hr were verified in the above manner, the remaining blocks containing observed severe local storms that occurred in the preceding hour were tabulated in the "observed severe," "predicted no severe" category in table 1.

This method depends heavily on accurate coding of the additive data section of the MDR report and the complete reporting of all severe local storms. If, for some reason, the additive data are coded incorrectly or transmitted improperly or, if a severe storm goes unreported, these verification statistics reflect the efficiency of the system, as well as the evaluation of the guidance criteria.

DESCRIPTION OF VERIFICATION SCORES

The following scores were computed for each radar station's area of responsibility, for each MDR block and for the total MDR grid:

a. Probability of detection (POD) (Donaldson 1975), also described by Panofsky and Brier (1958) as "prefigurance,"

$$POD = X \div (X+Y).$$

b. False alarm ratio (FAR) (Donaldson 1975),

$$FAR = Z \div (X+Z).$$

c. Critical success index (CSI) (Donaldson 1975), commonly known as "threat score" (Palmer and Allen 1949),

$$CSI = X \div (X+Y+Z).$$

d. Bias, defined as predicted divided by observed,

$$Bias = (X+Z) \div (X+Y).$$

e. Skill score (SS), defined as the number of correct predictions minus those expected correct by chance, divided by total predictions minus those expected correct by chance.

If we let N equal the total number of general thunderstorm blocks, then

$$N = X + Y + Z + W .$$

If we let A equal the predictions of severe local storms expected to verify by chance, then

$$A = (X+Z) \times (X+Y) \div N .$$

If we let B equal the predictions of non-severe local storms expected to verify by chance, then

$$B = (Y+W) \times (Z+W) \div N .$$

Therefore,

$$SS = [(X+W) - (A+B)] \div [N - (A+B)].$$

VERIFICATION RESULTS

Data for April through June and for July through September 1974 are given in tables 3 and 4, respectively. Both tables show that a very small percentage of the MDR thunderstorm blocks were associated with observed severe local storms. The number of MDR thunderstorm blocks almost doubled from spring (53,790) to summer (94,984), while the number of observed severe local storm blocks in summer (795) was less than half of the spring observed severe local storm blocks (2,041). Also note, that while the number of observed severe local storm blocks decreased from spring to summer, the number of severe predictions increased (3,822 to 5,285). This indicates that radar identification of thunderstorms which ultimately are accompanied by tornadoes, hail, or damaging winds is much more difficult in summer than in spring. In spite of this difficulty, 90.8% of the spring thunderstorms and 94.0% of the summer thunderstorms were successfully recognized as non-severe. Table 5, shows there was a significant increase in MDR thunderstorm blocks from the spring of 1974 to the spring of 1975. However, the percentage change in each category was very little.

Table 6 gives verification scores computed from the contingency tables. Probability of detection remained about the same for the two 1974 seasons. As expected, the false alarm ratio jumped from 0.77 to 0.93, and was accompanied by a decline in the critical success index from 0.18 to 0.06. Probability of detection improved in the spring of 1975 over 1974, but the bias worsened. Other scores showed little change. A bias of 1.00 indicates no bias, so a bias of 1.87 indicates that almost twice as many predictions of severe storms were made as were observed. The summer bias indicates well over 6 times as many predictions as observations. A skill score of 1.00 indicates perfect forecasts. Therefore, 0.27 for spring and 0.11 for summer are low.

Table 3.--Contingency table for April through June 1974.

Observed	Predicted		
	Severe	No Severe	Total
Severe	890 (1.7%)	1151 (2.1%)	2041 (3.8%)
No Severe	2932 (5.4%)	48817 (90.8%)	51749 (96.2%)
Total	3822 (7.1%)	49968 (92.9%)	53790 (100%)

Table 4.--Contingency table for July through September 1974.

Observed	Predicted: Severe	Predicted: No Severe	Predicted: Total
Severe	360 (0.4%)	435 (0.4%)	795 (0.8%)
No Severe	4925 (5.2%)	89264 (94.0%)	94189 (99.2%)
Total	5285 (5.6%)	89699 (94.4%)	94984 (100%)

Table 5.--Contingency table for April through June 1975.

Observed	Predicted: Severe	Predicted: No Severe	Predicted: Total
Severe	1269 (2.0%)	893 (1.4%)	2162 (3.4%)
No Severe	4652 (7.2%)	57620 (89.4%)	62272 (96.6%)
Total	5921 (9.2%)	58513 (90.8%)	64434 (100%)

Table 6.--Probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), bias, and skill score (SS) in detecting severe local storms for the spring and summer of 1974, and the spring of 1975.

	POD	FAR	CSI	BIAS	SS
April - June 1974	0.44	0.77	0.18	1.87	0.27
July - September 1974	0.45	0.93	0.06	6.65	0.11
April - June 1975	0.59	0.79	0.19	2.74	0.28

The Appendix contains computer listings of some additional verification results. The first page is a verification listing by radar station. The data for each station are for the MDR blocks assigned to that station for reporting purposes. Some stations have more blocks than others, some stations have blocks beyond effective radar range, and some stations have blocks over water where no severe storm data are archived. Therefore, when comparing station scores, allowances should be made for these discrepancies. The 10 stations with the highest skill scores for the spring months were as follows:

1974				1975			
GRI	0.49	OKC	0.42	UMN	0.49	OKC	0.34
MKC	0.45	BNA	0.40	GRI	0.48	MSP	0.34
LIC	0.45	MMO	0.39	LIC	0.40	LIT	0.34
JAN	0.44	EEW	0.38	DTW	0.38	HDO	0.33
DSM	0.43	GCK	0.37	STL	0.35	MMO	0.33

Their combined skill score was 0.44 compared with 0.27 for all stations in 1974 and 0.38 compared with 0.28 for all stations in 1975.

Some of these stations stayed in the top 10 in the summer months. Listed below are the stations with the 10 highest skill scores for the summer of 1974.

GRI	0.51	BRO	0.31
DSM	0.43	PIT	0.29
HON	0.38	UMN	0.25
MKC	0.34	MMO	0.21
GCK	0.33	AMA	0.20

Their combined skill score was 0.34 compared with 0.11 for all stations. Grand Island, Nebraska topped the list for both spring and summer, and its score increased for the summer months, which was a reversal of the general trend. It would be interesting to know why Kansas City, who appeared in the top 10 for both spring and summer in 1974, dropped to a skill score of only 0.03 in the spring of 1975. Another interesting case is Wichita. Why do the MDR data show that no pluses were ever reported by Wichita?

The critical success indices and skill scores are printed with reference to a geography background in pages 4 through 9 of the Appendix. These charts give a better picture of scores in geographcial areas, densely populated areas, administrative areas, etc. Scores were multiplied by 100 for these maps to save plotting space. The number of 0's on the critical success index maps is quite disturbing. They indicate no success whatever in issuing warnings of severe local storms from radar echo characteristics. Turning to the skill score maps, perfect scores of 100 are plotted as 99 to save plotting space. Zeroes indicate those predicted correct were the same as chance. Minus scores indicate chance would have been a better predictor than the radar severe storm criteria. Amarillo, Little Rock, Kansas City, and a few other stations have higher scores for their own MDR block than for their whole area. However, this does not hold true for all radar stations. It does appear that in general scores in the MDR block containing the radar site and those adjacent are higher than scores two or more blocks removed from the radar site.

SUMMARY AND FUTURE PLANS

The verification scheme described here admittedly has some weak points. However, if anything, it is weighted decidedly in favor of the radar operator and the system within which he works. No previous verification statistics are available for comparison, but scores in areas some distance from radar sites especially during the summer months appear quite low. A few stations managed skill scores in the 40's and critical success indices in the 30's under the present system. If forecasters at a few stations can do this well, perhaps forecasters at other stations could profit from their expertise. Current radar warning criteria have been in operational use nearly three years now. Perhaps it is time to update the criteria with the latest experience and research.

As severe storm data become available, we plan to continue this verification and make reports from time to time. Anyone interested in more details (i.e., statistics by MDR grid blocks and additional maps) may contact the Techniques Development Laboratory.

REFERENCES

Foster, D. S., and R. M. Reap, 1973: Archiving of manually-digitized radar data. TDL Office Note 73-6, National Weather Service, NOAA, Silver Spring, Md., 5 pp.

Foster, D. S., and R. M. Reap, 1975: Thunderstorm and severe local storm frequency distributions for 1974 derived from manually-digitized radar data and severe local storm reports. Proc. Ninth Conf. on Severe Local Storms, Am. Meteor. Soc., Boston, Mass., 64-67.

Donaldson, R. J., Jr., R. M. Dyer, and M. J. Kraus, 1975: An objective evaluator of techniques for predicting severe weather events. Proc. Ninth Conf. on Severe Local Storms, Am. Meteor. Soc., Boston, Mass., 321-326.

Mogil, H. M., 1974: Evaluation of severe weather and thunderstorm forecasts using manually-digitized radar data and the SELS severe weather log. Proc. Fifth Conf. on Forecasting and Analysis, Am. Meteor. Soc., Boston, Mass., 270-275.

Moore, P. L., A. D. Cummings, and D. L. Simth, 1974: The National Weather Service manually-digitized radar program and its application to precipitation probability forecasting. Proc. Fifth Conf. on Forecasting and Analysis, Am. Meteor. Soc., Boston, Mass., 69-74.

Palmer, W. C., and R. A. Allen, 1949: Note on accuracy of forecasts concerning the rain problem. Unpublished manuscript, U. S. Weather Bureau, Washington, D. C., 4 pp.

Panofsky, H. A., and G. W. Brier, 1958: Some applications of statistics to meteorology. The Pennsylvania State University, University Park, Pa., 224 pp.

APPENDIX

Verification of MDR criteria for predicting that a thunderstorm echo will be accompanied by severe local storm activity.

Verification of MDR criteria for predicting that an MDR thunderstorm echo will be accompanied by severe local storm activity. Verification period, April through June 1974.

RADAR STATION	SP/SO	NSP/SO	SP/NSO	NSP/NSO	POD	FAR	CSI	BIAS	SKILL S
ACY	12.	18.	59.	785.	0.400	0.831	0.135	2.367	0.199
AHN	11.	36.	77.	1404.	0.234	0.875	0.089	1.872	0.128
AMA	29.	32.	99.	664.	0.475	0.773	0.181	2.098	0.230
AQQ	7.	4.	183.	1741.	0.636	0.963	0.036	17.273	0.060
AYS	16.	6.	149.	1638.	0.727	0.903	0.094	7.500	0.153
BNA	64.	21.	99.	376.	0.753	0.607	0.348	1.918	0.396
BRO	1.	4.	18.	949.	0.200	0.947	0.043	3.800	0.076
BUF	9.	16.	27.	593.	0.360	0.750	0.173	1.440	0.261
CHH	0.	1.	9.	223.	0.0	1.000	0.0	9.000	-0.008
CHS	19.	12.	148.	1757.	0.613	0.886	0.106	5.387	0.169
CKL	18.	23.	160.	1261.	0.439	0.899	0.090	4.341	0.124
CVG	14.	40.	31.	438.	0.259	0.689	0.165	0.833	0.209
DAB	3.	14.	52.	2376.	0.176	0.945	0.043	3.235	0.073
DSM	48.	89.	24.	1713.	0.350	0.333	0.298	0.526	0.431
DTW	14.	45.	22.	859.	0.237	0.611	0.173	0.610	0.260
EEW	17.	31.	17.	608.	0.354	0.500	0.262	0.708	0.378
EVV	9.	40.	10.	985.	0.184	0.526	0.153	0.388	0.245
EYW	0.	0.	0.	2775.	0.0	0.0	0.0	0.0	0.0
GCK	31.	45.	31.	427.	0.408	0.500	0.290	0.816	0.369
GLS	1.	2.	32.	805.	0.333	0.970	0.029	11.000	0.049
GRI	84.	50.	86.	1011.	0.627	0.506	0.382	1.269	0.491
HAT	16.	6.	51.	677.	0.727	0.761	0.219	3.045	0.330
HDO	21.	0.	131.	957.	1.000	0.862	0.138	7.238	0.217
HON	15.	36.	22.	750.	0.294	0.595	0.205	0.725	0.305
ICT	0.	96.	0.	623.	0.0	0.0	0.0	0.0	0.0
ILM	30.	14.	158.	1252.	0.682	0.840	0.149	4.273	0.220
JAN	37.	13.	73.	1351.	0.740	0.664	0.301	2.200	0.436
LCH	17.	18.	113.	1416.	0.486	0.869	0.115	3.714	0.177
LIC	15.	12.	20.	407.	0.556	0.571	0.319	1.296	0.447
LIT	42.	29.	117.	1259.	0.592	0.736	0.223	2.239	0.319
MAF	22.	17.	67.	506.	0.564	0.753	0.208	2.282	0.280
MIA	0.	4.	50.	3116.	0.0	1.000	0.0	12.500	-0.002
MKC	17.	24.	13.	698.	0.415	0.433	0.315	0.732	0.454
MMO	56.	63.	70.	955.	0.471	0.556	0.296	1.059	0.392
MSP	1.	47.	4.	687.	0.021	0.800	0.019	0.104	0.026
NHK	13.	18.	48.	750.	0.419	0.787	0.165	1.968	0.245
NHZ	0.	3.	11.	148.	0.0	1.000	0.0	3.667	-0.030
NPA	0.	2.	9.	1838.	0.0	1.000	0.0	4.500	-0.002
NQA	24.	27.	46.	972.	0.471	0.657	0.247	1.373	0.361
NYC	8.	18.	43.	440.	0.308	0.843	0.116	1.962	0.150
OKC	47.	24.	70.	482.	0.662	0.598	0.333	1.648	0.417
PIT	18.	33.	56.	362.	0.353	0.757	0.168	1.451	0.183
SEP	46.	23.	232.	630.	0.667	0.835	0.153	4.029	0.166
SIL	9.	8.	81.	1718.	0.529	0.900	0.092	5.294	0.155
STL	11.	69.	5.	1030.	0.137	0.313	0.129	0.200	0.210
TBW	30.	3.	231.	2725.	0.909	0.885	0.114	7.909	0.188
TRI	17.	23.	53.	1008.	0.425	0.757	0.183	1.750	0.276
UMN	10.	32.	13.	571.	0.238	0.565	0.182	0.548	0.273

SP/SO - Severe storms predicted/severe storms observed
NSP/SO - No severe storms predicted/severe storms observed
SP/NSO - Severe storms predicted/no severe storms observed
NSP/NSO- No severe storms predicted/no severe storms observed

Verification of MDR criteria for predicting that an MDR thunderstorm echo will be accompanied by severe local storm activity. Verification period, July through September 1974.

RADAR STATION	SP/SO	NSP/SO	SP/NSO	NSP/NSO	POD	FAR	CSI	BIAS	SKILL S
ACY	22.	22.	174.	1418.	0.500	0.888	0.101	4.455	0.146
AHN	4.	5.	126.	2526.	0.444	0.969	0.030	14.444	0.052
AMA	5.	7.	29.	1037.	0.417	0.853	0.122	2.833	0.204
AQQ	0.	3.	138.	3662.	0.0	1.000	0.0	46.000	-0.002
AYS	7.	5.	398.	3478.	0.583	0.983	0.017	33.750	0.028
BNA	7.	3.	180.	943.	0.700	0.963	0.037	18.700	0.055
BRO	2.	3.	6.	2278.	0.400	0.750	0.182	1.600	0.306
BUF	4.	9.	96.	579.	0.308	0.960	0.037	7.692	0.039
CHH	5.	4.	98.	573.	0.556	0.951	0.047	11.444	0.067
CHS	6.	3.	226.	4106.	0.667	0.974	0.026	25.778	0.046
CKL	8.	7.	122.	2087.	0.533	0.938	0.058	8.667	0.099
CVG	1.	6.	5.	554.	0.143	0.833	0.083	0.857	0.144
DAB	4.	4.	129.	3878.	0.500	0.970	0.029	16.625	0.053
DSM	10.	18.	8.	1666.	0.357	0.444	0.278	0.643	0.427
DTW	21.	12.	122.	916.	0.636	0.853	0.135	4.333	0.199
EEW	4.	15.	59.	1026.	0.211	0.937	0.051	3.316	0.073
EVV	1.	20.	19.	1348.	0.048	0.950	0.025	0.952	0.035
EYW	0.	1.	0.	6023.	0.0	0.0	0.0	0.0	0.004
GCK	10.	4.	30.	264.	0.714	0.750	0.227	2.857	0.325
GLS	4.	7.	31.	1628.	0.364	0.886	0.095	3.182	0.166
GRI	28.	16.	32.	980.	0.636	0.533	0.368	1.364	0.515
HAT	2.	1.	204.	2152.	0.667	0.990	0.010	68.667	0.017
HDO	2.	1.	82.	2433.	0.667	0.976	0.024	28.000	0.044
HON	35.	12.	86.	1049.	0.745	0.711	0.263	2.574	0.381
ICT	0.	12.	0.	572.	0.0	0.0	0.0	0.0	0.0
ILM	0.	2.	479.	3745.	0.0	1.000	0.0	99.000	-0.001
JAN	7.	12.	77.	2427.	0.368	0.917	0.073	4.421	0.125
LCH	19.	8.	414.	2999.	0.704	0.956	0.043	16.037	0.069
LIC	6.	15.	29.	786.	0.286	0.829	0.120	1.667	0.189
LIT	6.	7.	143.	2023.	0.462	0.960	0.038	11.462	0.064
MAF	1.	1.	42.	1133.	0.500	0.977	0.023	21.500	0.041
MIA	5.	4.	273.	8068.	0.556	0.982	0.018	30.889	0.033
MKC	15.	18.	34.	805.	0.455	0.694	0.224	1.485	0.336
MMO	22.	14.	101.	477.	0.611	0.821	0.161	3.417	0.205
MSP	2.	31.	9.	952.	0.061	0.818	0.048	0.333	0.076
NHK	16.	11.	186.	1101.	0.593	0.921	0.075	7.481	0.107
NHZ	12.	12.	83.	653.	0.500	0.874	0.112	3.958	0.159
NPA	3.	9.	28.	4958.	0.250	0.903	0.075	2.583	0.137
NOA	8.	12.	104.	1213.	0.400	0.929	0.065	5.600	0.098
NYC	22.	30.	135.	1204.	0.423	0.860	0.118	3.019	0.164
OKC	3.	6.	16.	500.	0.333	0.842	0.120	2.111	0.196
PIT	20.	11.	74.	959.	0.645	0.787	0.190	3.032	0.289
SEP	9.	7.	173.	1647.	0.563	0.951	0.048	11.375	0.076
SIL	11.	6.	254.	3472.	0.647	0.958	0.041	15.588	0.070
STL	1.	31.	1.	678.	0.031	0.500	0.030	0.063	0.054
TBW	5.	6.	381.	4898.	0.455	0.987	0.013	35.091	0.021
TRI	2.	5.	20.	912.	0.286	0.909	0.074	3.143	0.128
UMN	5.	5.	24.	941.	0.500	0.828	0.147	2.900	0.245

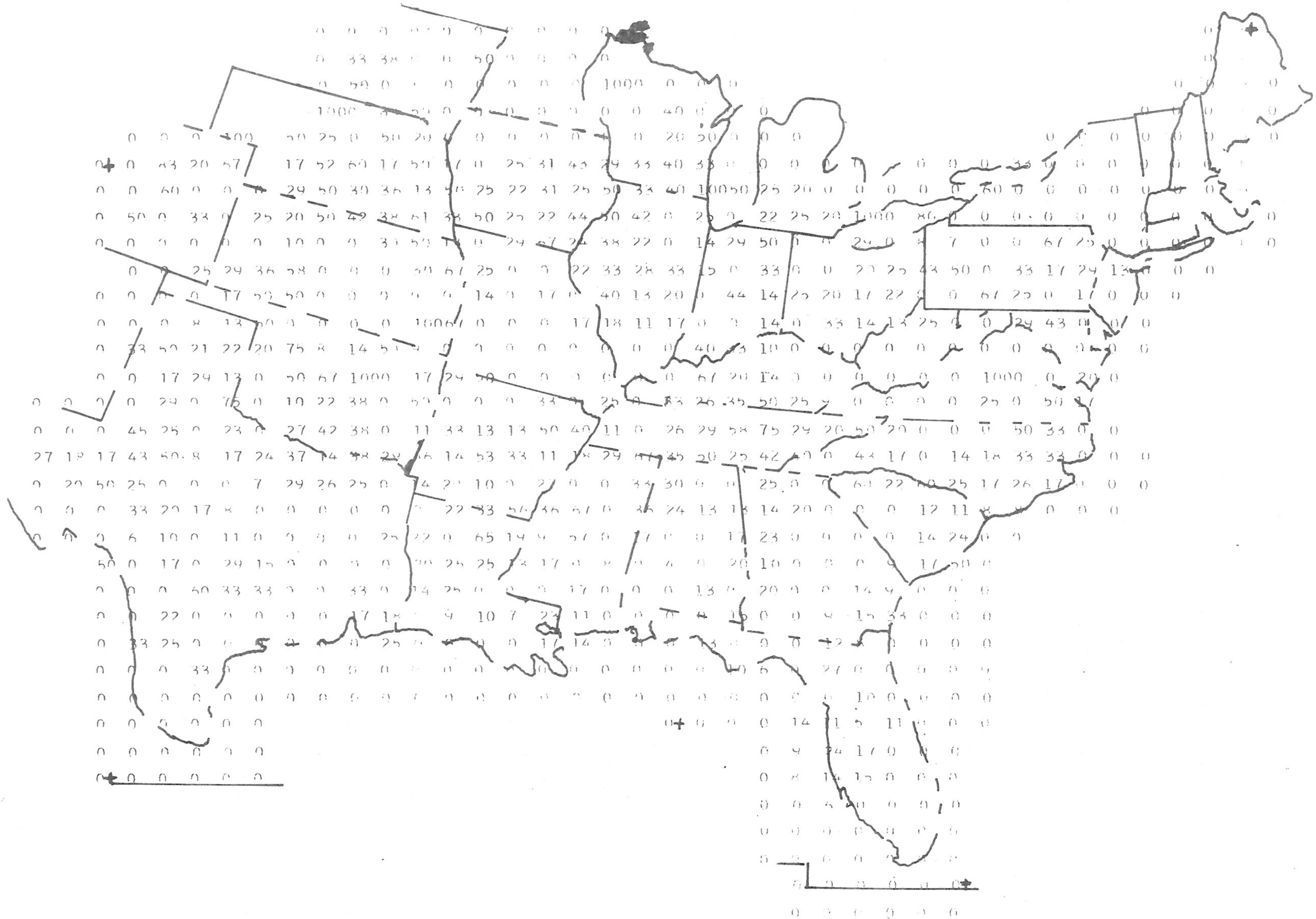
SP/SO - Severe storms predicted/severe storms observed
NSP/SO - No severe storms predicted/severe storms observed
SP/NSO - Severe storms predicted/no severe storms observed
NSP/NSO - No severe storms predicted/no severe storms observed

Verification of MDR criteria for predicting that an MDR thunderstorm echo will be accompanied by severe local storm activity. Verification period, April through June 1975.

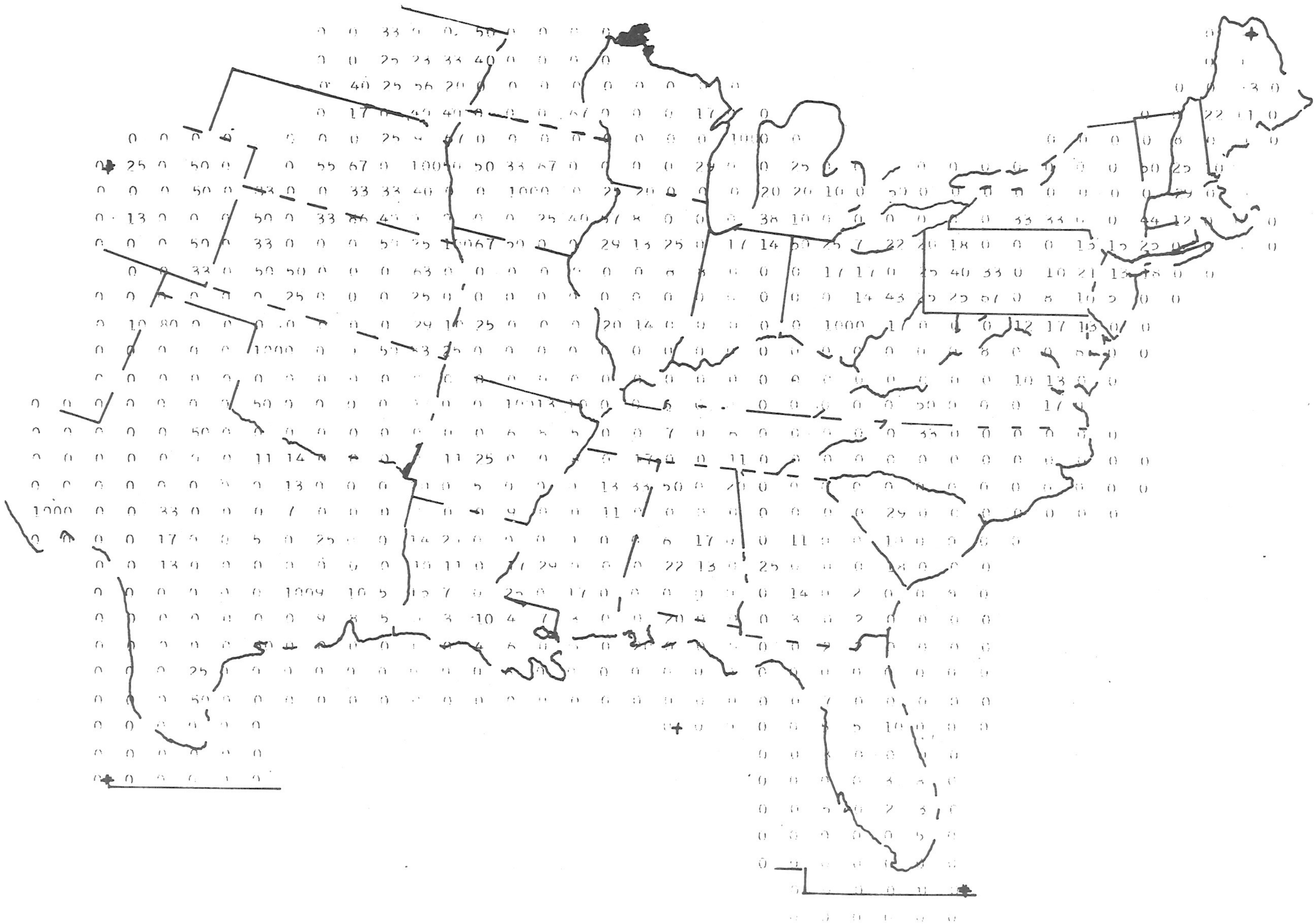
RADAR STATION	SP/SO	NSP/SO	SP/NSO	NSP/NSO	POD	FAR	CSI	BIAS	SKILL S
ACY	19.	13.	216.	1143.	0.594	0.919	0.077	7.344	0.106
AHN	29.	7.	113.	770.	0.806	0.796	0.195	3.944	0.281
AMA	56.	13.	185.	1020.	0.812	0.768	0.220	3.493	0.303
AQQ	4.	1.	43.	1168.	0.800	0.915	0.083	9.400	0.148
AYS	29.	11.	112.	1849.	0.725	0.794	0.191	3.525	0.299
BNA	20.	9.	139.	543.	0.690	0.874	0.119	5.483	0.154
BRO	7.	5.	109.	1409.	0.583	0.940	0.058	9.667	0.097
BUF	0.	15.	11.	227.	0.0	1.000	0.0	0.733	0.053
CHH	1.	0.	24.	200.	1.000	0.960	0.040	25.000	0.069
CHS	29.	12.	134.	1758.	0.707	0.822	0.166	3.976	0.259
CKL	7.	12.	125.	1704.	0.368	0.947	0.049	6.947	0.076
CVG	2.	15.	34.	573.	0.118	0.944	0.039	2.118	0.040
DAB	14.	23.	61.	2062.	0.378	0.813	0.143	2.027	0.232
DSM	32.	38.	107.	1347.	0.457	0.770	0.181	1.986	0.261
DTW	44.	34.	92.	1807.	0.564	0.676	0.259	1.744	0.380
EEW	12.	18.	31.	414.	0.400	0.721	0.197	1.433	0.275
EVV	8.	18.	12.	442.	0.308	0.600	0.211	0.769	0.316
EYW	0.	0.	0.	2047.	0.0	0.0	0.0	0.0	0.0
GCK	45.	18.	156.	581.	0.714	0.776	0.205	3.190	0.251
GLS	27.	8.	95.	1459.	0.771	0.779	0.208	3.486	0.321
GRI	99.	26.	147.	1257.	0.792	0.598	0.364	1.968	0.477
HAT	10.	1.	142.	1686.	0.909	0.934	0.065	13.818	0.113
HDO	69.	7.	233.	2035.	0.908	0.772	0.223	3.974	0.330
HON	50.	42.	103.	719.	0.543	0.673	0.256	1.663	0.323
ICT	0.	52.	0.	737.	0.0	0.0	0.0	0.0	0.0
ILM	22.	3.	175.	1886.	0.880	0.888	0.110	7.880	0.181
JAN	39.	29.	124.	2364.	0.574	0.761	0.203	2.397	0.312
LCH	38.	25.	139.	2226.	0.603	0.785	0.188	2.810	0.289
LIC	30.	22.	45.	416.	0.577	0.600	0.309	1.442	0.401
LIT	73.	23.	215.	1814.	0.760	0.747	0.235	3.000	0.335
MAF	43.	14.	207.	873.	0.754	0.828	0.163	4.386	0.216
MIA	8.	9.	112.	3108.	0.471	0.933	0.062	7.059	0.109
MKC	1.	43.	6.	1241.	0.023	0.857	0.020	0.159	0.030
MMO	112.	49.	210.	697.	0.696	0.652	0.302	2.000	0.329
MSP	18.	42.	20.	934.	0.300	0.526	0.225	0.633	0.337
NHK	21.	13.	141.	1281.	0.618	0.870	0.120	4.765	0.183
NHZ	2.	3.	27.	161.	0.400	0.931	0.063	5.800	0.077
NPA	3.	7.	23.	2608.	0.300	0.885	0.091	2.600	0.162
NQA	28.	17.	185.	1252.	0.622	0.869	0.122	4.733	0.176
NYC	11.	17.	153.	835.	0.393	0.933	0.061	5.857	0.071
OKC	67.	33.	157.	970.	0.670	0.701	0.261	2.240	0.339
PIT	11.	14.	37.	811.	0.440	0.771	0.177	1.920	0.274
SEP	79.	25.	281.	1231.	0.760	0.781	0.205	3.462	0.267
SIL	16.	8.	219.	2160.	0.667	0.932	0.066	9.792	0.107
STL	25.	47.	33.	1135.	0.347	0.569	0.238	0.806	0.351
TRW	3.	8.	44.	1657.	0.273	0.936	0.055	4.273	0.094
TRI	11.	39.	22.	962.	0.220	0.667	0.153	0.660	0.236
UMN	36.	29.	36.	779.	0.554	0.500	0.356	1.108	0.486

SP/SO - Severe storms predicted/severe storms observed
NSP/SO - No severe storms predicted/severe storms observed
SP/NSO - Severe storms predicted/no severe storms observed
NSP/NSO - No severe storms predicted/no severe storms observed

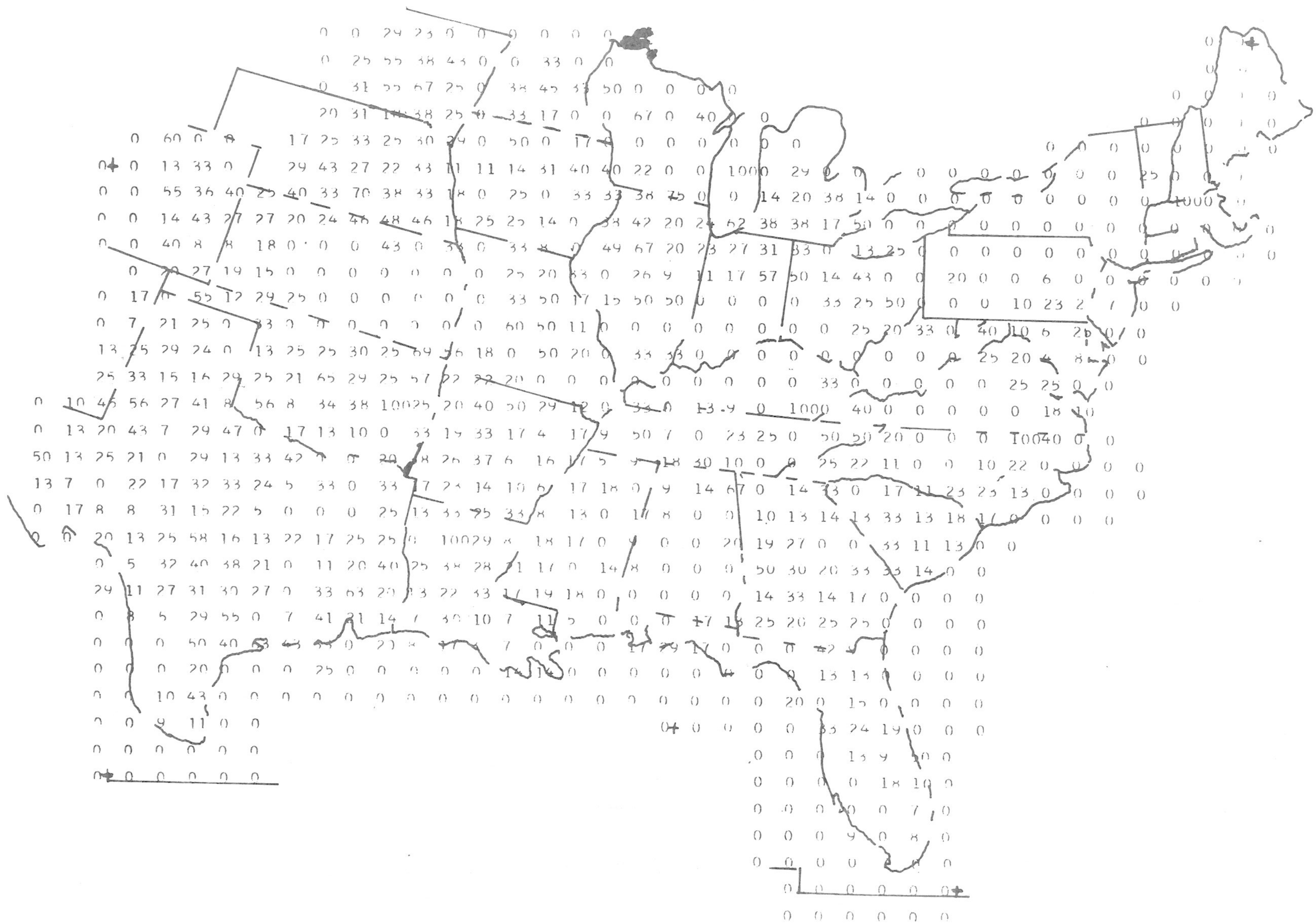
Critical success index (x 100) for period, April through June 1974.



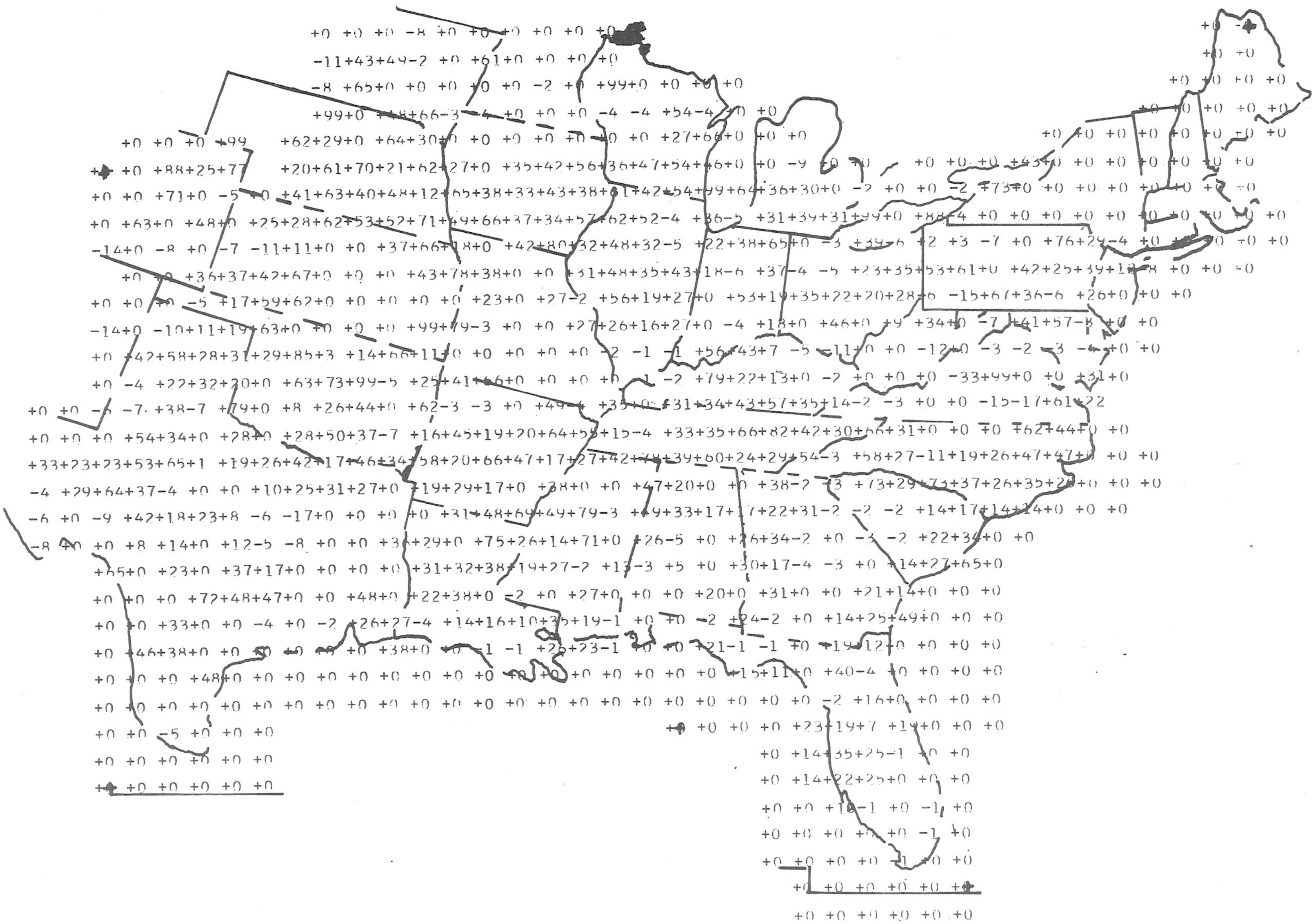
Critical success index (x 100) for period, July through September 1974.



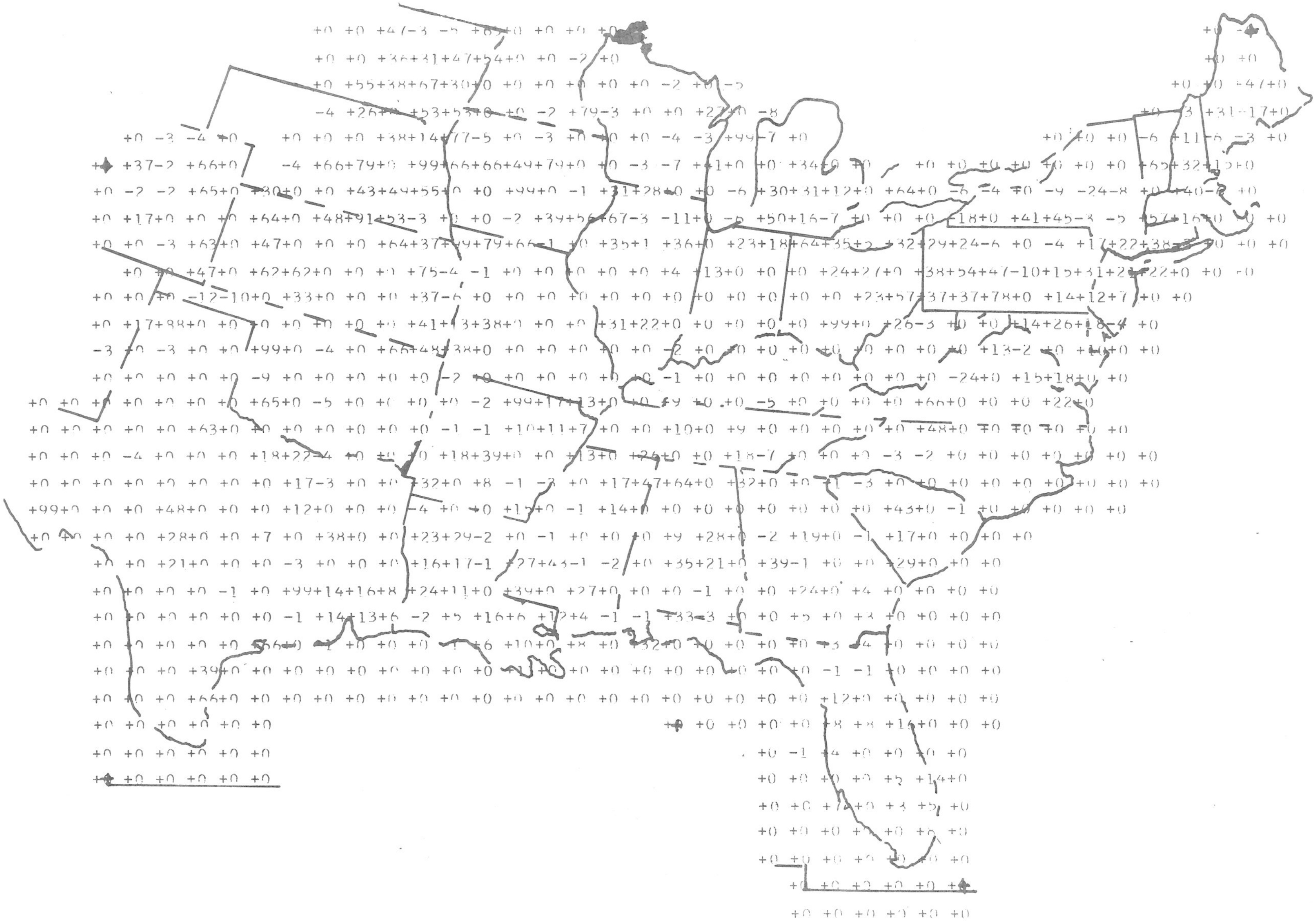
Critical success index (x 100) for period, April through June 1975.



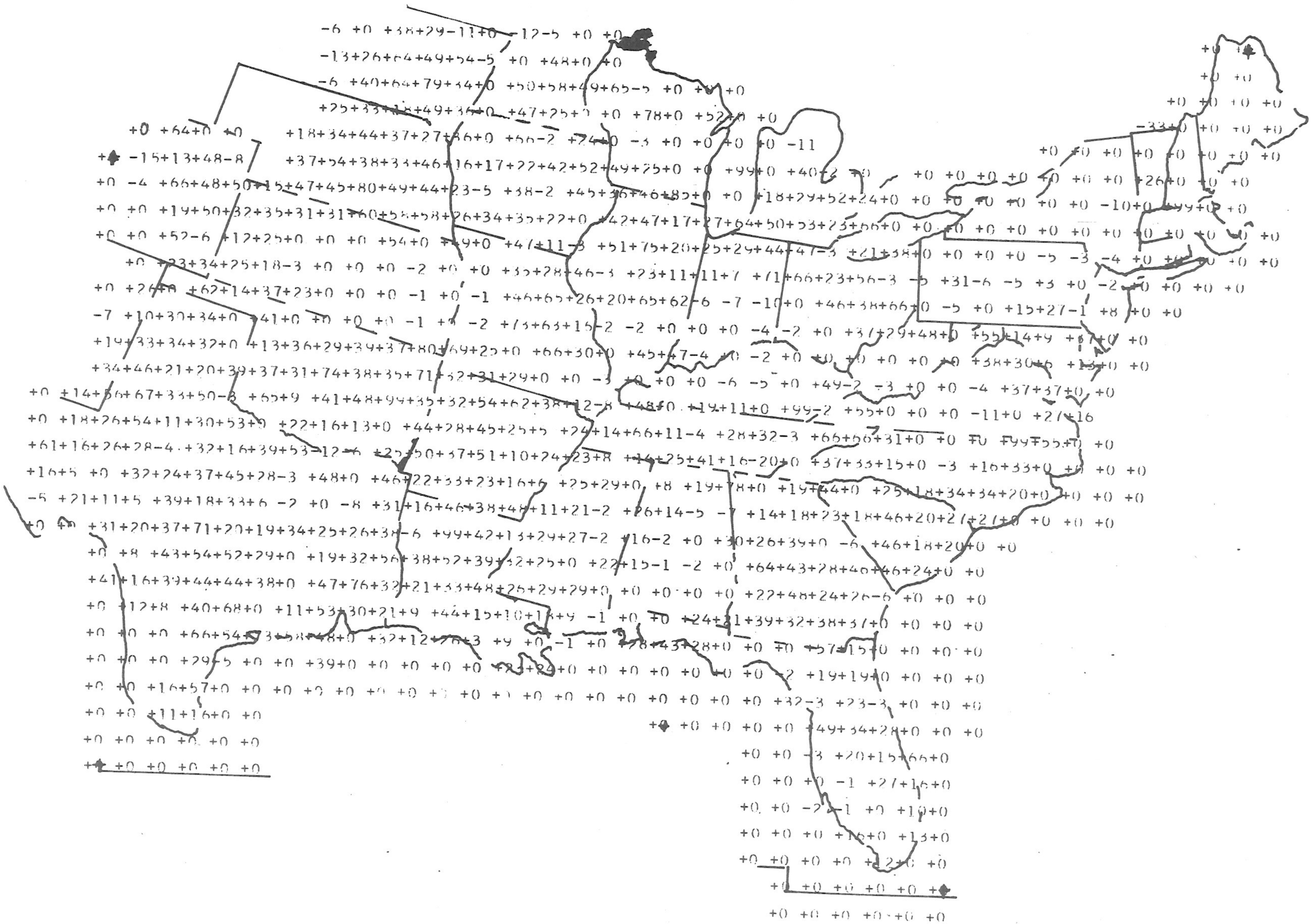
Skill score (x 100) for period, April through June 1974.



Skill score (x 100) for period, July through September 1974.



Skill score (x 100) for period, April through June 1975.



SUPPLEMENT TO

NOAA Technical Memorandum TDL-60

Verification of Severe Local Storm Warnings Resulting from Radar Guidance Criteria

While NOAA Technical Memorandum TDL-60 was being reviewed and printed severe storm data for the summer of 1975 became available to TDL. These data permitted the completion of the verification for 1975. The following tables and figures give verification scores for the summer months of 1975

Table 5a. Contingency table for July through September 1975.

Observed	Predicted		
	Severe	No Severe	Total
Severe	341 (0.3%)	542 (0.5%)	883 (0.8%)
No Severe	4109 (3.9%)	100759 (95.3%)	104868 (99.2%)
Total	4450 (4.2%)	101301 (95.8%)	105751 (100%)

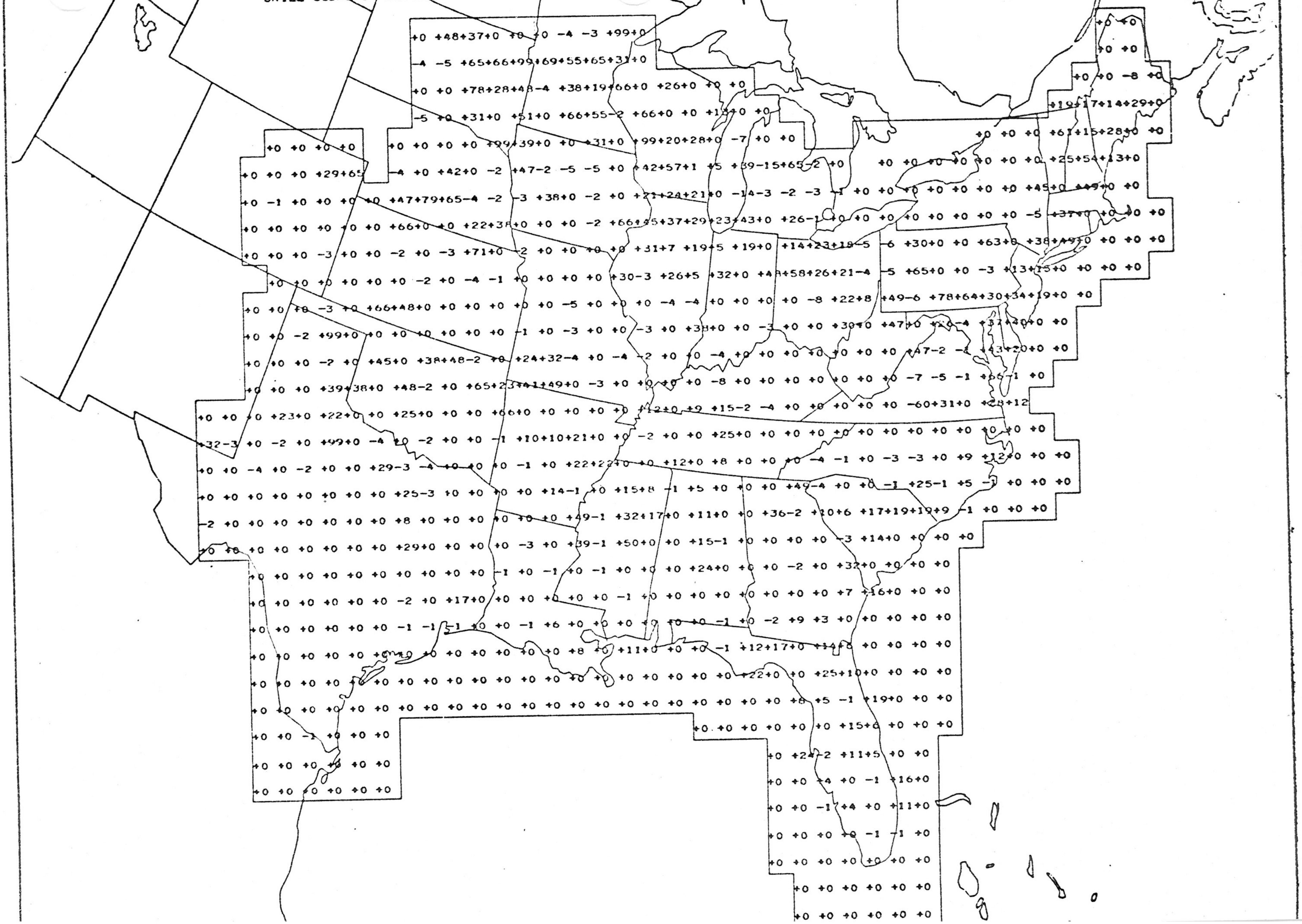
Table 6a. Probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), bias, and skill score (SS) in detecting severe local storms for the summer of 1975.

	POD	FAR	CSI	BIAS	SS
July-September 1975	0.39	0.92	0.07	5.04	0.12

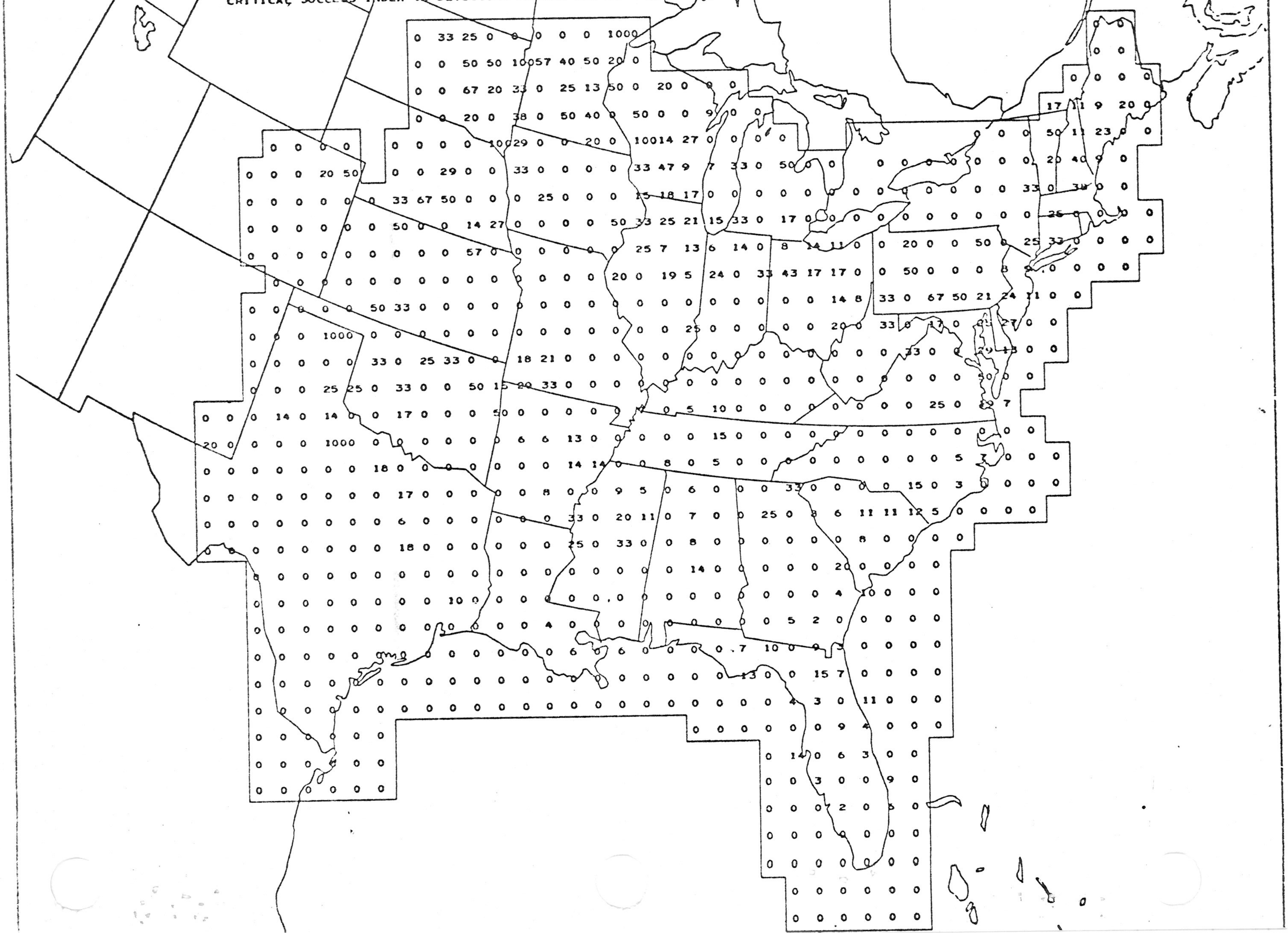
VERIFICATION OF MDR CRITERIA FOR PREDICTING SEVERE CONVECTIVE CELLS
BASED ON MDR ADDITIVE DATA AND SEVERE LOCAL STORM DATA
FOR PERIOD 75070100 THROUGH 75093023

RADAR STATION	SP/SO	NSP/SO	SP/NSO	NSP/NSO	POD	FAR	CSI	BIAS	SKILL S
ACY	23.	31.	104.	1921.	0.426	0.819	0.146	2.352	0.226
AHN	6.	10.	137.	1194.	0.375	0.958	0.039	8.938	0.055
AMA	7.	4.	46.	1458.	0.636	0.868	0.123	4.818	0.209
AQQ	3.	5.	132.	7076.	0.375	0.978	0.021	16.875	0.040
AYS	9.	5.	265.	3438.	0.643	0.967	0.032	19.571	0.056
BNA	7.	7.	171.	1352.	0.500	0.961	0.038	12.714	0.057
BRO	0.	4.	8.	3017.	0.0	1.000	0.0	2.000	-0.002
BUF	1.	23.	3.	275.	0.042	0.750	0.037	0.167	0.050
CHH	4.	0.	40.	450.	1.000	0.909	0.091	11.000	0.154
CHS	10.	8.	167.	3820.	0.556	0.944	0.054	9.833	0.095
CKL	4.	5.	102.	2760.	0.444	0.962	0.036	11.778	0.064
CVG	0.	13.	4.	606.	0.0	1.000	0.0	0.308	-0.010
DAB	10.	11.	220.	5718.	0.476	0.957	0.041	10.952	0.074
DSM	4.	27.	23.	1207.	0.129	0.852	0.074	0.871	0.118
DTW	12.	19.	65.	1720.	0.387	0.844	0.125	2.484	0.203
EEW	28.	20.	159.	579.	0.583	0.850	0.135	3.896	0.156
EVV	1.	10.	16.	415.	0.091	0.941	0.037	1.545	0.043
EYW	0.	0.	3.	4214.	0.0	1.000	0.0	99.000	0.001
GCK	2.	6.	10.	658.	0.250	0.833	0.111	1.500	0.188
GLS	0.	6.	14.	2564.	0.0	1.000	0.0	2.333	-0.003
GRI	19.	15.	75.	1397.	0.559	0.798	0.174	2.765	0.273
HAT	8.	2.	166.	3494.	0.800	0.954	0.045	17.400	0.082
HDO	0.	4.	7.	2448.	0.0	1.000	0.0	1.750	-0.002
HON	27.	19.	51.	1162.	0.587	0.654	0.278	1.696	0.408
ICT	0.	20.	3.	530.	0.0	1.000	0.0	0.150	-0.010
ILM	11.	16.	254.	4688.	0.407	0.958	0.039	9.815	0.066
JAN	4.	8.	43.	2603.	0.333	0.915	0.073	3.917	0.129
LCH	1.	6.	146.	3798.	0.143	0.993	0.007	21.000	0.010
LIC	2.	10.	16.	787.	0.167	0.889	0.071	1.500	0.118
LIT	10.	8.	152.	2227.	0.556	0.938	0.059	9.000	0.099
MAF	1.	6.	60.	1351.	0.143	0.984	0.015	8.714	0.021
MIA	2.	5.	211.	5061.	0.286	0.991	0.009	30.429	0.016
MKC	0.	9.	21.	1072.	0.0	1.000	0.0	2.333	-0.012
MMO	33.	5.	157.	651.	0.868	0.826	0.169	5.000	0.232
MSP	17.	31.	21.	1346.	0.354	0.553	0.246	0.792	0.377
NHK	21.	37.	89.	2052.	0.362	0.809	0.143	1.897	0.223
NHZ	18.	11.	85.	502.	0.621	0.825	0.158	3.552	0.215
NPA	0.	1.	18.	5009.	0.0	1.000	0.0	18.000	0.0
NQA	7.	6.	230.	2325.	0.538	0.970	0.029	18.231	0.047
NYC	19.	23.	98.	1478.	0.452	0.838	0.136	2.786	0.209
OKC	5.	10.	26.	733.	0.333	0.839	0.122	2.067	0.196
PIT	15.	40.	62.	1091.	0.273	0.805	0.128	1.400	0.184
SEP	8.	6.	227.	1782.	0.571	0.966	0.033	16.786	0.052
SIL	4.	2.	203.	4195.	0.667	0.981	0.019	34.500	0.035
STL	1.	34.	19.	1113.	0.029	0.950	0.019	0.571	0.015
TBW	6.	13.	255.	6405.	0.316	0.977	0.022	13.737	0.038
TRI	0.	13.	3.	1556.	0.0	1.000	0.0	0.231	-0.003
UMN	14.	8.	59.	987.	0.636	0.808	0.173	3.318	0.272

SKILL SCORE IN DETECTING SEVERE CONVECTIVE FOR PERIOD 75070100 THROUGH 75093023 (TIMES 100)



CRITICAL SUCCESS INDEX IN DETECTING SEVERE CONVECTIVE CELLS FOR PERIOD 75070100 THROUGH 75093023 (TIMES 100)



(Continued from inside front cover)

WBTM TDL 25 Charts Giving Station Precipitation in the Plateau States From 850- and 500-Millibar Lows During Winter. August F. Korte, Donald L. Jorgensen, and William H. Klein, September 1969. (PB-187-476)

WBTM TDL 26 Computer Forecasts of Maximum and Minimum Surface Temperatures. William H. Klein, Frank Lewis, and George P. Casely, October 1969. (PB-189-105)

WBTM TDL 27 An Operational Method for Objectively Forecasting Probability of Precipitation. Harry R. Glahn and Dale A. Lowry, October 1969. (PB-188-660)

WBTM TDL 28 Techniques for Forecasting Low Water Occurrences at Baltimore and Norfolk. James M. McClelland, March 1970. (PB-191-744)

WBTM TDL 29 A Method for Predicting Surface Winds. Harry R. Glahn, March 1970. (PB-191-745)

WBTM TDL 30 Summary of Selected Reference Material on the Oceanographic Phenomena of Tides, Storm Surges, Waves, and Breakers. N. Arthur Pore, May 1970. (PB-192-449)

WBTM TDL 31 Persistence of Precipitation at 108 Cities in the Conterminous United States. Donald L. Jorgensen and William H. Klein, May 1970. (PB-193-599)

WBTM TDL 32 Computer-Produced Worded Forecasts. Harry R. Glahn, June 1970. (PB-194-262)

WBTM TDL 33 Calculation of Precipitable Water. L. P. Harrison, June 1970. (PB-193-600)

WBTM TDL 34 An Objective Method for Forecasting Winds Over Lake Erie and Lake Ontario. Celso S. Barrientos, August 1970. (PB-194-586)

WBTM TDL 35 Probabilistic Prediction in Meteorology: a Bibliography. Allan H. Murphy and Roger A. Allen, June 1970. (PB-194-415)

WBTM TDL 36 Current High Altitude Observations--Investigation and Possible Improvement. M. A. Alaka and R. C. Elvander, July 1970. (COM-71-00003)

NOAA Technical Memoranda

NWS TDL-37 Prediction of Surface Dew Point Temperatures. R. C. Elvander, February 1971. (COM-71-00253)

NWS TDL-38 Objectively Computed Surface Diagnostic Fields. Robert J. Bermowitz, February 1971. (COM-71-00301)

NWS TDS-39 Computer Prediction of Precipitation Probability for 108 Cities in the United States. William H. Klein, February 1971. (COM-71-00249)

NWS TDL-40 Wave Climatology for the Great Lakes. N. A. Pore, J. M. McClelland, C. S. Barrientos, and W. E. Kennedy, February 1971. (COM-71-00368)

NWS TDL-41 Twice-Daily Mean Monthly Heights in the Troposphere Over North America and Vicinity. August F. Korte, June 1971. (COM-71-00826)

NWS TDL-42 Some Experiments With a Fine-Mesh 500-Millibar Barotropic Model. Robert J. Bermowitz, August 1971. (COM-71-00958)

NWS TDL-43 Air-Sea Energy Exchange in Lagrangian Temperature and Dew Point Forecasts. Ronald M. Reap, October 1971. (COM-71-01112)

NWS TDL-44 Use of Surface Observations in Boundary-Layer Analysis. H. Michael Mogil and William D. Bonner, March 1972. (COM-72-10641)

NWS TDL-45 The Use of Model Output Statistics (MOS) To Estimate Daily Maximum Temperatures. John R. Annett, Harry R. Glahn, and Dale A. Lowry, March 1972. (COM-72-10753)

NWS TDL-46 SPLASH (Special Program To List Amplitudes of Surges From Hurricanes) I. Landfall Storms. Chester P. Jelesnianski, April 1972. (COM-72-10807)

NWS TDL-47 Mean Diurnal and Monthly Height Changes in the Troposphere Over North America and Vicinity. August F. Korte and DeVer Colson, August 1972. (COM-72-11132)

NWS TDL-48 Synoptic Climatological Studies of Precipitation in the Plateau States From 850-, 700-, and 500-Millibar Lows During Spring. August F. Korte, Donald L. Jorgensen, and William H. Klein, August 1972. (COM-73-10069)

NWS TDL-49 Synoptic Climatological Studies of Precipitation in the Plateau States From 850-Millibar Lows During Fall. August F. Korte and DeVer Colson, August 1972. (COM-74-10464)

NWS TDL-50 Forecasting Extratropical Storm Surges For the Northeast Coast of the United States. N. Arthur Pore, William S. Richardson, and Herman P. Perrotti, January 1974. (COM-74-10719)

NWS TDL-51 Predicting the Conditional Probability of Frozen Precipitation. Harry R. Glahn and Joseph R. Bocchieri, March 1974. (COM-74-10909/AS)

NWS TDL-52 SPLASH (Special Program to List Amplitudes of Surges From Hurricanes) II. General Track and Variant Storm Conditions. Chester P. Jelesnianski, March 1974.

NWS TDL-53 A Comparison Between the Single Station and Generalized Operator Techniques for Automated Prediction of Precipitation Probability. Joseph R. Bocchieri, September 1974. (COM-74-11763/AS)

NWS TDL-54 Climatology of Lake Erie Storm Surges at Buffalo and Toledo. N. Arthur Pore, Herman P. Perrotti, and William S. Richardson, December 1974.

NWS TDL-55 Dissipation, Dispersion and Difference Schemes. Paul E. Long, Jr., May 1975. (COM-75-10972/AS)

NWS TDL-56 Some Physical and Numerical Aspects of Boundary Layer Modeling. Paul E. Long, Jr., May 1975. (COM-75-10980)

NWS TDL-57 A Predictive Boundary Layer Model. Wilson A. Shaffer and Paul E. Long, Jr., May 1975.

NWS TDL-58 A Preliminary View of Storm Surges Before and After Storm Modifications for Alongshore-Moving Storms. Chester P. Jelesnianski and Celso S. Barrientos, October 1975. (PB247362)

NWS TDL-59 Assimilation of Surface, Upper Air, and Grid-Point Data in the Objective Analysis Procedure for a Three-Dimensional Trajectory Model. Ronald M. Reap, February 1976.

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