3.6

Reprinted from Preprint Volume: 12th Conference on Severe Local Storms, Jan. 11-15, 1982; San Antonio, Tex. Published by the American Meteorological Society, Boston, Mass.

FORECASTING SEVERE THUNDERSTORMS:

A BRIEF EVALUATION OF ACCEPTED TECHNIQUES

Robert A. Maddox

NOAA, Environmental Research Laboratories
Office of Weather Research and Modification
Boulder, Colorado 80303

Charles A. Doswell III

NOAA, National Weather Service
National Severe Storms Forecast Center
Kansas City, Missouri 64106

1. INTRODUCTION

Since March of 1948, when operational severe thunderstorm forecasting first began (Miller, 1972), many forecast techniques have been developed and utilized. Most of these techniques have their origins in semi-empirical research from the late 1940's to the late 1950's (e.g. Fawbush et al., 1951; Fawbush and Miller, 1954; Beebe and Bates, 1955; Magor, 1959; and Newton, 1962). By the end of that period, a serious division had developed between the research and forecasting elements of meteorology (Doswell et al., 1981). While many of the methods developed during the formative period of severe thunderstorm forecasting have their origins in sound physical principles, few have been subjected to a rigorous scientific examination in light of recent advances in our understanding. The advent of computer models has been accompanied by a trend away from synoptic meteorology and toward increasing dependence on numerical guidance (Snellman, 1977). Regrettably, many valuable insights have been lost in the process, and forecasting severe thunderstorms has largely been separated from basic physical understanding. The original studies suggest many useful avenues of applied research which have been forgotten, or at least de-emphasized. Instead, many of these topics have been translated into forecasting "rules" which are presented without the accompanying physical reasoning.

In his severe storm forecasting manual Miller (1972) presented a summary of important parameters and suggested guidelines for rating the intensity of these parameters. A simplified version of his guidelines is shown in Table 1. It should be quite obvious that these rules (as well as most of the other works cited above) key upon the highly baroclinic synoptic setting (predominantly in the spring) that leads to widespread outbreaks of severe thunderstorms and tornadoes. Indeed these are just the type situations that are handled best (Galway, 1975) by forecasters at the National Severe Storms Forecast Center (NSSFC). However, it is well documented (e.g. Golden and Purcell, 1975; Doswell, 1976; Maddox, 1976, Maddox and Deitrich, 1981; and Maddox and Doswell, 1981) that significant severe thunderstorm episodes often occur within relatively weak large-scale meteorological settings. Thus, the forecaster must be extremely cautious if general guidelines, such as those of Table 1, are used to evaluate the severe thunderstorm threat. In particular, it must be realized that generally accepted rules apply to one particular type of severe storm environment. Three specific cases are examined in the next section and the Table 1 guidelines are evaluated for each case. These have been chosen to illustrate one situation where the guidelines apply well and two situations where they do not. We suggest several alternate forecasting parameters that seem to be important in cases of weak synoptic forcing.

2. EVALUATION OF THREE SEVERE STORM EVENTS

2.1 The case of 22/23 September 1980

During the afternoon of 22 September 1980 a strong cold front pushed through the mid-Mississippi Valley and lower Great Lakes Region accompanied by an intense, pre-frontal squall line. Numerous severe storms were reported and property damage was widespread; however, Storm Data accounts indicated only 16 personal injuries. A composite chart for 00Z on the 23rd is shown in Fig. 1 and an evaluation of the strength of the parameters from Table 1 is presented in Table 2 for both 12Z on the 22nd and 00Z on the 23rd. Both the composite and Table 2 show this to be a "classic" severe storm episode (despite its occurrence in the fall rather than in the spring!) with all but 3 of the parameters reaching Miller's "strong" level by 00Z. The only characteristics of this event that do not fit the classic pattern are: the moderate levels of instability, the lack of intersecting low-level and upper-level jets [note that the low-level southwesterly jet is essentially parallel to the upper-level jet (see McNulty, 1977)], the moist axis and temperature ridge were coincident and the strongest 500 mb height falls occurred to the north and northwest of the storm area. Obviously, these slight deficiencies were more than compensated for by the overall intensity of the synoptic setting.

Table 1
Summary of Key Parameters (after Miller, 1972)

RANK	PARAMETER	WEAK (W)	MODERATE (M)	STRONG (S)
1	500 mb vorticity Advection	Neutral or NVA	PVA-Contours Cross Vorticity Pattern $\leq 30^{\circ}$	PVA - Contours Cross Vorticity Pattern $> 30^{\circ}$
2	Stability-Totals Index	TI $\leq$ 50	50 > TI $\leq$ 55	TI > 55
3	500 MB wind speed	WS $\leq$ 35 kt	35 < WS $\leq$ 50 kt	WS > 50 kt
4	300 - 200 MB wind Speed (upper-level max)	WS $\leq$ 55 kt	55 < WS $\leq$ 85 kt	WS > 85 kt
5	850 MB wind speed	WS $\leq$ 20 kt	20 < WS < 35 kt	WS $\geq$ 35 kt
6	850 MB Dewpoint	$T_d \leq 8^{\circ}C$	$8 < T_d \leq 12^{\circ}C$	$T_d > 12^{\circ}C$
7	850 MB Temp Ridge Location	East of Moist axis	Over moist axis	West of moist axis
8	700 MB Temp No. Change Line (12-h)	Winds cross line $\leq 20^{\circ}$	Winds cross line > 20 and $\leq 40^{\circ}$	Winds cross line $> 40^{\circ}$
9	700 MB Dry Intrusion	Not available or weak 700 MB winds	Winds from dry to moist intrude at angle of $< 40^{\circ}$ and are $\geq$ 15 kt	Winds intrude at an angle of $\geq 40^{\circ}$ and are $\geq$ 25 kt
10	12-h Surface Pres-ure Fall	< 1 MB	1 to 5 MB	> 5 MB
11	500 MB Height Change (12-h)	< 30 M	$\geq$ 30 M and $\leq$ 60 M	> 60 M
12	Surface Pressure over threat area	$\geq$ 1010 MB	< 1010 MB and $\geq$ 1005 MB	< 1005 MB
13	Surface Dewpoint	$T_d \leq 55^{\circ}F$	$55 < T_d < 65^{\circ}F$	$T_d \geq 65^{\circ}F$

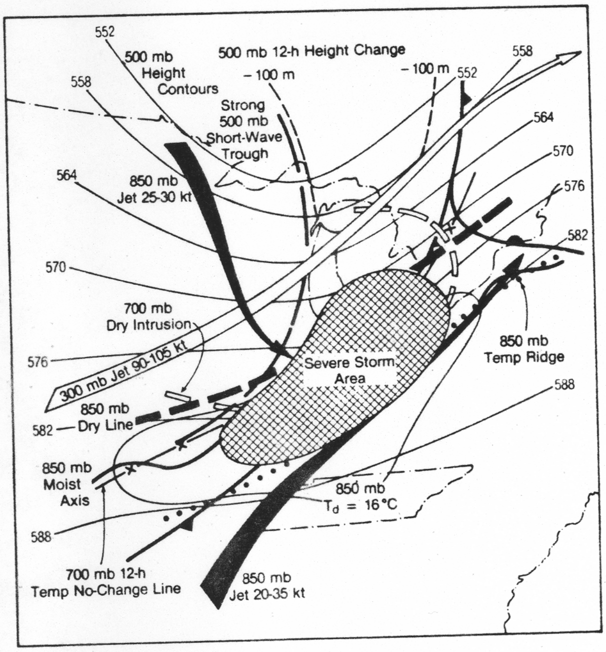

Figure 1. Composite severe storm forecast parameter chart (after Miller, 1972) for 00Z 23 September 1980.

Table 2
Summary of Key Parameters for 22/23 September 1980

PARAMETER NO.	12Z	STRENGTH	00Z	STRENGTH
1	NVA	W	PVA	S
2	51	M	51	M
3	50 kt	M	60 kt	S
4	60 kt	M	90 kt	S
5	35 kt	S	35 kt	S
6	14-16°C	S	17°C	S
7	Coincident	M	Coincident	M
8	Available	S	Available	S
9	Available	S	Available	S
10	0 to +2 MB	W	-3 to -8 MB	M-S
11	-30 M	M	-50 M	M
12	1007 to 1010 MB	W-M	1002 to 1010 MB	M-S
13	66 - 72°F	S	72 to 75°F	S

2.2 The case of 19/20 April 1981

During the evening of 19 April 1981 several tornadoes struck Tulsa, Oklahoma, and its suburbs. Although only a few severe storms were reported, the tornadoes were quite strong and produced heavy property damage with 57 people injured and 5 deaths. A composite chart for 00Z on the 20th is shown in Fig. 2 and an evaluation of the strength of the parameters from Table 1 is presented in Table 3. Note that even though this event occurred during April, the synoptic setting was quite weak. The severe storms occurred in conjunction with a weak short-wave trough at 500 mb that was moving eastward beneath a pronounced blocking ridge. The 850 mb moist axis and temperature ridge were positioned south and east of the storm area. Many of the "classic" severe storm features were either not present or were rated only as weak. However, the low-level moisture indictors were strong and the surface pattern was very favorable (see Tegtmeir, 1974; Moller, 1980; and Maddox et al., 1980). Although very significant severe thunderstorms occurred, an evaluation of the situation based upon the parameter Table provides few clues to the forecaster.

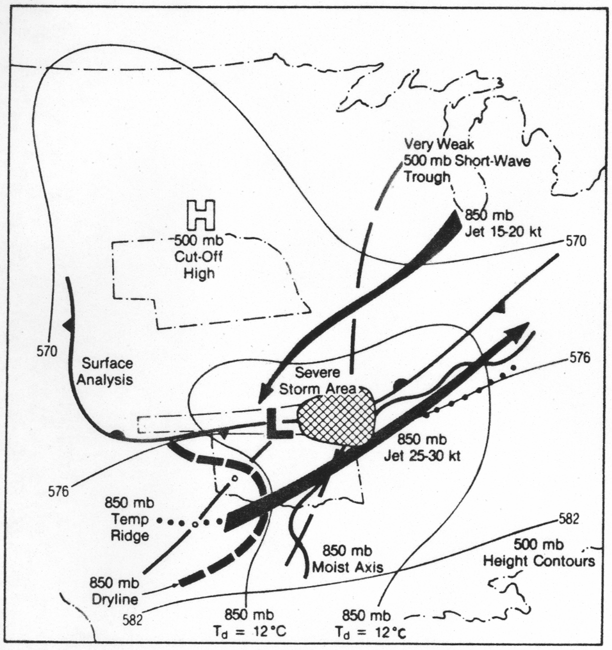

Figure 2. Composite severe storm forecast parameter chart (after Miller, 1972) for 00Z 20 April 1981.

2.3 The case of 3/4 June 1980

During the evening of 3 June 1980 severe thunderstorms struck eastern Nebraska; the most significant storm spawned at least 6 tornadoes in the Grand Island area. Storm Data reports indicate, in addition to very heavy property damage, more than 200 injuries and 5 deaths. Once again, although the region affected by severe storms was not particularly large, the storms were highly significant. A composite chart for 00Z on the 4th is shown in Fig. 3, with an evaluation of the strength of the parameters from Table 1 presented in Table 4. This event's synoptic setting was also quite weak, especially in contrast to the "classic" severe storm setting. Note that

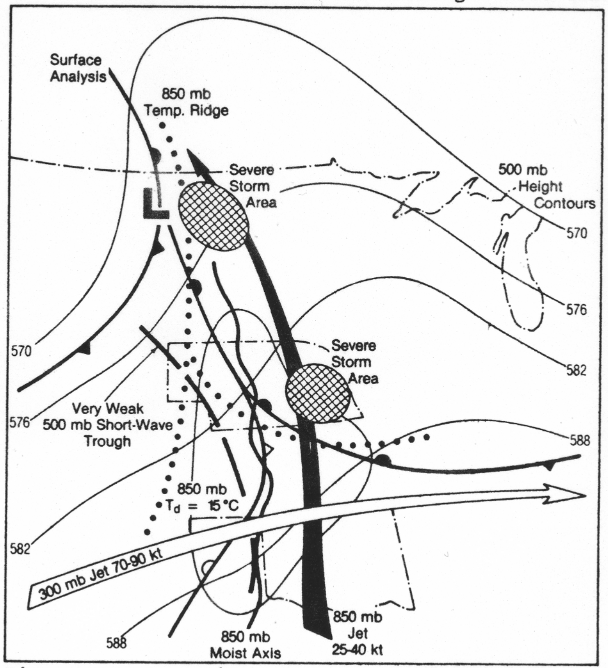

Figure 3. Composite severe storm forecast parameter chart (after Miller, 1972) for 00Z 4 June 1980.

Table 3
Summary of Key Parameters for 19/20 April 1981

PARAMETER NO.	12Z	STRENGTH	00Z	STRENGTH
1	NVA	W	NVA	W
2	48	W	53	M
3	30 kt	W	30 kt	W
4	50 kt	W	50 kt	W
5	40 kt	S	25 kt	M
6	9°C	M	13°C	S
7	None	W	None	W
8	None	W	None	W
9	None	W	None	W
10	-4.5 MB	M	-4.2 MB	M
11	-40 M	M	+40 M	W
12	1011.5 MB	W	1007.3 MB	M
13	62°F	M	66°F	S

Table 4
Summary of Key Parameters for 3/4 June 1980

PARAMETER NO.	12Z	STRENGTH	00Z	STRENGTH
1	NVA	W	PVA	M
2	42	W	59	S
3	25 kt	W	25 kt	W
4	45 kt	W	55 kt	W
5	20 kt	W	25 kt	M
6	-2°C	W	16°C	S
7	None	W	None in area	W
8	None	W	None	W
9	None	W	None	W
10	+5 MB	W	-1 MB	M
11	+50 M	W	+70 M	W
12	1011.2 MB	W	1010.2 MB	W
13	66°F	S	72°F	S

the severe storms (a second area of severe storms over the Dakotas is not discussed here) occurred as a very weak short-wave trough moved through the large-scale ridge position and approached a surface warm front (again a very favorable surface pattern for tornadic storms, see Maddox et al., 1980). The orientations of the 850 mb temperature and moisture axes were much different than those described by Miller as being conducive to severe storms. Although upper-and lower-jets intersected, the severe storms occurred considerably north of the upper-jet and to the northwest of a well defined speed maximum in the upper-jet. Again, many of the classic features and parameters were either lacking or were quite weak. Most notable were the very high low-level moisture contents and the extreme instability (note that the dramatic changes from morning to evening make it all the more difficult for the forecaster to recognize this situation's potential threat).

3. DISCUSSION

These three case studies illustrate that classic severe thunderstorm forecast guidelines and techniques work well within strongly baroclinic, intense synoptic settings, but, they also illustrate that outbreaks of intense and potentially very dangerous severe thunderstorms can also occur within considerably more benign and subtle large-scale environments. The latter two cases are precisely the most important type events from the operational point-of-view because they pose the greatest challenge to NSSFC forecasters (Galway, 1975). Both of the weak settings illustrated here were similar to events discussed by Maddox and Doswell (1981) in that very pronounced lower-tropospheric warm air advection was apparently the dominant mechanism that triggered release of the conditional instability (see also Hales, 1982, this volume). Indeed, these two events were also similar to the patterns conducive to development of large convective complexes (see Maddox, 1982, this preprint volume) and in both cases large nocturnal storm complexes did develop. It seems clear that better criteria than those of Table 1 for monitoring the severe thunderstorm threat within weakly baroclinic environments need to be developed. Such criteria should focus upon the important physical mechanisms leading to strong storms within such an environment. In particular, the importance of favorable surface patterns and pronounced east/west thermal boundaries, the degree of conditional instability and vertical motion forced by lower-tropospheric warm advection need to be strongly emphasized.

4. REFERENCES

Beebe, R. G. and F. C. Bates, 1955: A mechanism for assisting in the release of convective instability. Mon. Wea. Rev., 83, 1-10.

Doswell, C. A. III, 1976: Subsynoptic scale dynamics as revealed by use of filtered surface data. NOAA Tech. Memo. ERL NSSL-79, 40 pp.

____________, L. R. Lemon and R. A. Maddox, 1981: Forecaster training-A review and analysis. Bull. Amer. Meteor. Soc., 62, No. 7.

Fawbush, E. J. and R. C. Miller, 1954: The types of air masses in which North American tornadoes form. Bull. Amer. Meteor. Soc., 35, 154-166.

____________, R. C. Miller and L. G. Starrett, 1951: An empirical method for forecasting tornado development. Bull. Amer. Meteor. Soc., 32, 1-9.

Galway, J. G., 1975: Relationship of tornado deaths to severe weather watch areas. Mon. Wea. Rev., 103, 737-741.

Golden, J. H. and D. Purcell, 1975: Photogrammetric velocities for the Great Bend Kansas tornado: Accelerations and asymmetries. Preprints Ninth Conf. on Severe Local Storms (Norman), AMS, Boston, Ma., 336-343.

Hales, J. E. Jr., 1982: Relationship of selected synoptic scale parameters to significant tornado occurrences in 1980. Preprints 12th Conf. on Severe Local Storms (San Antonio), AMS, Boston, Ma.

Maddox, R. A., 1976: An evaluation of tornado proximity wind and stability data. Mon. Wea. Rev., 104, 133-142.

____________, L. R. Hoxit and C. F. Chappell, 1980: A study of tornadic thunderstorm interactions with thermal boundaries. Mon. Wea. Rev., 108, 322-336.

____________ and W. Deitrich, 1981: Synoptic conditions associated with the simultaneous occurrence of significant severe thunderstorms and flash floods. Preprints Fourth Conf. on Hydrometeorology (Reno), AMS, Boston, Ma.

____________ and C. A. Doswell III, 1981: An examination of jetstream configurations, 500 mb vorticity advection and low-level thermal advection patterns during extended periods of intense convection. To be published in Mon. Wea. Rev.

Magor, B. W., 1959: Mesoanalysis: Some operational analysis techniques utilized in tornado forecasting. Bull. Amer. Meteor. Soc., 40, 499-511.

McNulty, R. P., 1978: On upper tropospheric kinematics and severe weather occurrence. Mon. Wea. Rev., 106, 662-672.

Miller, R. C., 1967: Notes on analysis and severe-storm forecasting procedures of the Military Weather Warning Center. AWS Tech. Report 200, Headquarters Air Weather Service, Scott AFB, 94 pp.

Newton, C. W., 1962: Dynamics of severe convective storms. NSSP Report No. 9, Washington D.C., 44 pp.

Tegtmeier, S. A., 1974: The role of the surface, subsynoptic, low pressure system in severe weather forecasting. M.S. Thesis, Univ. of Oklahoma, 66 pp.