FORECASTER'S FORUM

High Plains Severe Weather—Ten Years After

JOHN F. WEAVER
NOAA/NESDIS/RAMM Branch, Fort Collins, Colorado

NOLAN J. DOESKEN
Colorado Climate Center, Colorado State University, Fort Collins, Colorado

20 December 1990 and 21 February 1991

ABSTRACT

More than a decade ago, a study was published that identified a short list of precursor conditions for severe thunderstorms on the High Plains of the United States. The present study utilizes data from the summer months of ten convective seasons to estimate how well the criteria fare as a method of forecasting severe weather days in that region.

Results indicate that the technique produces a relatively high success rate in terms of detecting severe weather days for most years studied. False alarms are a bit high in an absolute sense (36% overall), but fall well within acceptable limits in the real world, where the philosophy of "better to overwarn, than underforecast" prevails.

1. Introduction

More than a decade ago, Doswell (1980) identified a set of what he called "typical" synoptic-scale features associated with High Plains severe thunderstorms. His final results were derived from the study of a limited set of severe weather events; namely, those that occurred during June and July 1979 on the High Plains of Montana, Wyoming, and Colorado. However, many of the variables described in his article were based on patterns described in other contexts in the literature (e.g., Henz 1973; Modahl 1979; Wetzel and Sinclair 1973), or during discussions between that author and regionally experienced forecasters. The iterated conditions include:

a) Upslope, low-level flow is usually present, which has resulted from the passage of a cold front one or more days before. There is an associated continental polar air mass, and a large, low-level anticyclone northeast of the forecast area. It is the flow around this "surface high" that is causing the upslope.

b) Flow at 500 mb is 10 m s^{-1} or greater, and has a westerly component. Large-scale lift (e.g., as associated with shortwave troughs) is weak, or missing entirely.

c) Surface dewpoints of 45°F or greater have returned to the area.

d) Thermal buoyancy is normally not very great.

Immediately following publication of the Doswell article, many High Plains forecasters adopted the criteria as the basis for a pattern-recognition technique for forecasting severe thunderstorms in the region. Personal interviews with these forecasters find a perceived high success rate for the approach. Recently, the authors decided to assemble a verification dataset to test the validity of this rather simple forecast scheme.

2. Data and procedures

The dataset for this study covers the months of May, June, July, and August for the years 1979–1988, inclusive. Figure 1 is a map showing the locations of all geographic references. The test region was defined to be the parts of Colorado and Wyoming contained between 39.2° and 41.3° N latitude, and between 103.0° and 105.3° W longitude (dashed area, Fig. 1). We chose our test region to correspond roughly to the area of interest for local research meteorologists who attempt to intercept and photograph severe thunderstorms. It includes both Ft. Collins, Colorado (home of Colorado State University—CSU), and Boulder, Colorado [home of several National Oceanic and Atmospheric Administration (NOAA) groups and of the National Center for Atmospheric Research (NCAR)] on the west, both Akron (AKO) and Limon (LIC) to the east, a small portion of Wyoming to the north, and the cen-

Corresponding author address: Mr. John Weaver, NOAA/NESDIS/RAMM Branch, Colorado State University, Fort Collins, CO 80523.

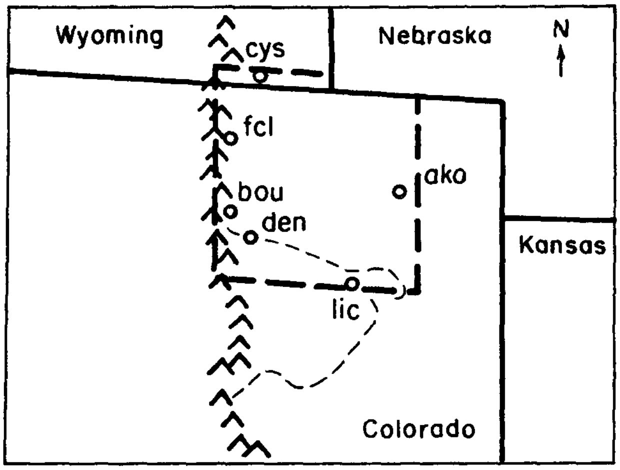

FIG. 1. Map of Colorado showing geographical features, city locations, and test area (dashed rectangle) referred to in text. The Palmer Lake Divide is indicated by thin dashed lines. Inverted Vs represent the front range of the Rocky Mountains.

tral axis of the Palmer Lake Divide—an important local terrain feature (e.g., Weaver and Toth 1990)—to the south. It also includes the Denver, Colorado, NWS forecast office (DEN), the Cheyenne, Wyoming, NWS forecast office (CYS), and the large metropolitan regions of Denver, Colorado, and Cheyenne, Wyoming.

For each day in the study period, a determination was made as to whether the data showed it to meet the Doswell criteria (severe day), or not meet the criteria (non-severe day). Criteria number 4—thermal buoyancy is not very great—was not applied, since 1) the condition, as intimated by Doswell, was not quantitative, 2) it is well known that strong instability is not a major factor in High Plains severe weather (e.g., Schultz 1989), and 3) local forecasters who use the Doswell technique do not specifically look for minimum instability (interviews and personal experience). The initial determination of a so-called "Doswell day" was made by a nonspecialized forecaster: one who had some basic meteorological knowledge, but no special background in forecasting thunderstorms. The meteorological data consisted of the morning (1200 UTC) 500-mb and surface analyses, and occasionally the 1800 UTC surface analysis whenever it was available and as it was needed to resolve borderline cases. Each year's dataset was then passed to an experienced forecaster for comparison to severe weather statistics.

Verification of severe weather relied entirely on information available from the publication *Storm Data* (NOAA 1979–88). The definition for severe weather is that of the National Weather Service: a tornado, and/or hail at least 3/4 inch (2 cm) in diameter, and/or winds causing damage or gusting over 50 kt (26 m s^{-1}). While severe weather reports in *Storm Data* often represent an "under-reporting," the reports for northeastern Colorado in the 1980s are somewhat better than average due to the presence of such a large meteorological community interested in observation, and the formal verification efforts of PROFS (Program for Regional Observation and Forecast Systems) beginning in 1983. In most cases, information from these supplemental sources *did* make it into *Storm Data.*

During the verification procedure, a few of the classifications made by the inexperienced meteorologist were changed. The actual number of such changes was relatively small—out of the 1230 case days, there were 93. The rules for the changes were simple. First, about 20% were due to outright errors in classification. The other 80% were made for so-called "marginal" days on which, for example, one variable fell slightly to one side or the other of a threshold value, causing an erroneous forecast to occur. Changes were made by an experienced Colorado severe-weather forecaster to reflect the fact that marginal cases occasionally require expert resolution. Such a change might occur, for example, if the 500-mb flow was a little weak (e.g., 8 m s^{-1}), but all other variables were within criteria. Or, perhaps, an early morning frontal passage (rather than on the previous day as specified by Doswell) resulted in late afternoon upslope and severe weather. Since real-time forecasters tend to "err on the side of caution," it is likely that in both such cases the "real" outlook would have included the possibility of severe weather. In these and similar cases, the classification was changed in favor of Doswell; that is, changed to resolve *minor* discrepancies in a manner which made the Doswell outlook correct. Of these changes, about two-thirds altered "non-severe" forecasts to a "severe" status, and the other third changed things in the opposite sense. Overall, the total changes amounted to a not quite 2% improvement in verification, which is fairly insignificant but gives consistent "benefit-of-the-doubt" to the Doswell scheme.

3. Results and discussion

Final statistics were broken into four categories:

a) severe forecast—severe occurred,
b) non-severe forecast—severe occurred,

TABLE 1. Verification statistics.

Year	a	b	c	d	POD	FAR	CSI
1979	24	8	10	81	.75	.29	.57
1980	13	9	11	90	.59	.46	.39
1981	18	8	11	86	.69	.38	.49
1982	18	11	8	86	.62	.31	.49
1983	10	17	6	90	.37	.38	.30
1984	10	13	10	90	.43	.50	.30
1985	16	7	7	93	.70	.30	.53
1986	12	6	7	98	.67	.37	.48
1987	18	13	9	83	.58	.33	.45
1988	10	11	4	98	.48	.29	.40
Overall	149	103	83	895	.59	.36	.44

DOSWELL FORECAST EVALUATION

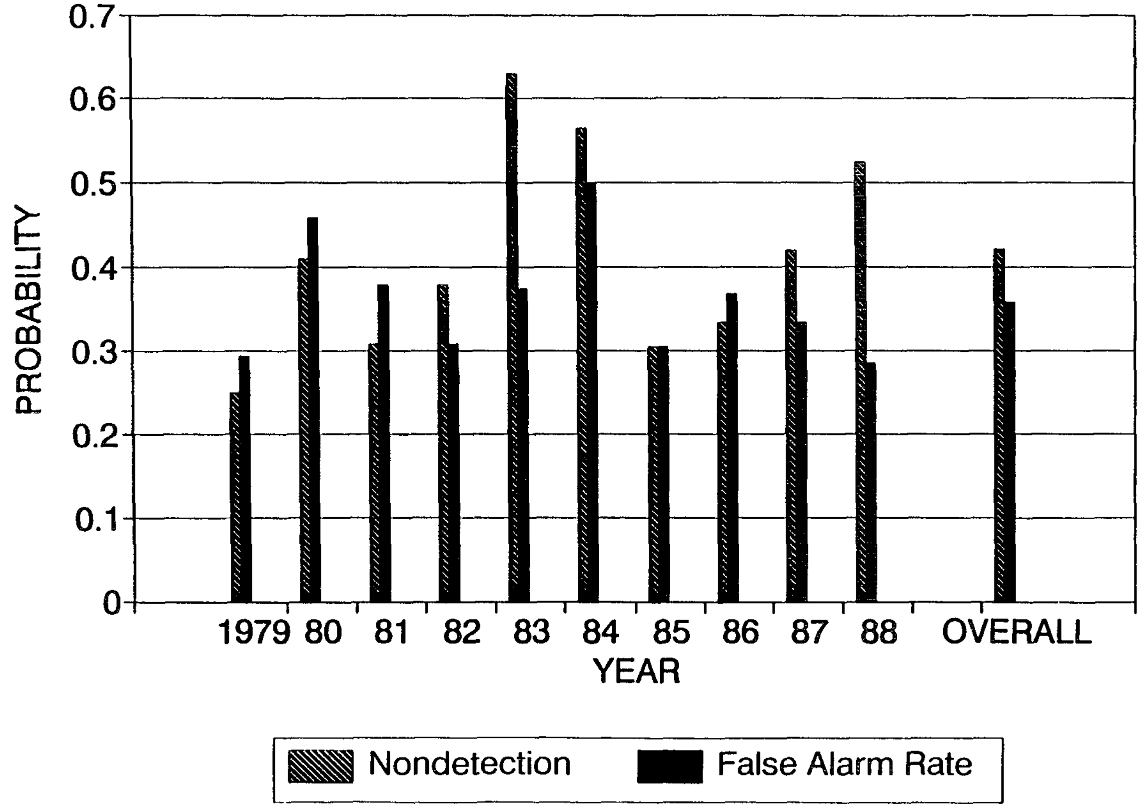

FIG. 2. Errors in forecasting severe thunderstorms. Hatched areas are Failure to Detect rates (1-POD), solid areas are False Alarm rates.

c) severe forecast—non-severe occurred,
d) non-severe forecast—non-severe occurred.

With the data broken into those categories, one can compute such basic verification statistics as the Probability of Detection = POD = a/(a + b), the False Alarm Ratio = FAR = c/(a + c), and the Critical Success Index = CSI = a/(a + b + c), as defined by Donaldson et al. (1975). Table 1 and Fig. 2 summarize these results. Note that the CSI does not consider category "d" the successful prediction of non-severe weather days. The CSI was chosen because we were interested in how well Doswell's technique handled the prediction of severe weather. It seemed to us that category "d" is a separate problem (i.e., the successful prediction of non-severe days) and a much simpler one to handle.

The most obvious feature of the statistical results is the apparent high success rate of the technique, given the small number of input variables and the ease of application. As shown in Table 1, the probability of detecting severe weather days using the Doswell criteria alone is nearly 60%! This is quite good, considering the scale of event being forecast. Furthermore, a respectably high CSI of 44% would be much higher, were it not for a fairly large FAR of 36%,[1] overall. However, it is hoped that, once alerted, the adept severe forecaster can eliminate a number of false alarms by studying other factors. By reducing the FAR to 25% (a reasonable goal), the CSI jumps to 63%. Also, as it turns out, the arbitrary choice of forecast area was not critical to the outcome. Out of the 1230 days tabulated, there were only 21 in which ±0.25° difference in either latitude or longitude, for the region verified, would have made a difference in the verification. Interestingly

[1] FARs of 35%–40% are not considered all that "high" in an operational environment where the philosophy of "better-safe-than-sorry" dominates. However, in a more general sense, 40% is not a satisfactory goal when it means that the public can count on the fact that they are receiving a false alarm 40% of time when they are told they are in danger—*more* when one considers the size of the warned area vs. that of the event.

enough, about half would have helped, and the other half hindered the statistical results.

Figure 2 is a graphical representation of both types of forecast errors. The hatched areas represent the *non*detection rates (1-POD)—that is, the percentage of cases where severe was *not* detected, while the solid areas are the false alarm rates. Notice that the false alarm rates are relatively consistent from year to year, and are all quite high (as noted above). On the other hand, notice that the nondetection rates are more variable from year to year. Thus, while the overall nondetection rate is about 42%, the rate for 1979 is 25%, while that for 1983 is 63%!

Another interesting finding of this study is the extreme variability identified—both in the year-to-year comparisons (ranging from only 14 severe days in 1988 up to 34 in 1979), as well as the wide range of variability in the Doswell verification results. The implication in the second factor is probably that not only does the number of severe-weather opportunities vary from year to year, but so do the synoptic situations associated with the generation of severe weather.

Doswell made a good point in his original study when he pointed out that synoptic patterns important in the western High Plains can be much different from those that trigger classic, midcontinent severe thunderstorm events. Weaver and Doesken (1990), looking at daily variability in severe weather in this region, identified a double-peaked seasonal distribution in the recurrence statistics for severe weather. Both the traditional June peak and a secondary peak occurring in late July and early August were found. The results suggested that other factors (besides the "Doswell" scenario, or the midcontinental classic mechanism) were at play. In fact, these authors suggested that the second peak was likely associated with additional moisture supplied by the southwest monsoonal flow over this part of the country in the mid to late summer. One is struck by the incredibly fortunate choice that Doswell made when he decided to do his study based on cases that occurred during the summer of 1979. As is clearly seen, the overall technique provides an excellent overview for severe-storm potential for *most years*. However, there are some obvious outliers (e.g., 1983, 1984) where the approach did not seem to have nearly as much success as it does most years. If Doswell had chosen to do his study during 1984, for example, one wonders if the paper would have been written at all.

Ten years worth of statistics following the publication of a set of select criteria for identifying severe thunderstorm days on the High Plains indicate that the technique, though quite simple to apply, is relatively effective. It is now incumbent on the community to build on this knowledge. Research is currently underway at CSU to improve these High Plains severe thunderstorm forecasts. There are two avenues being pursued. In one, we are studying other data sources in hopes of lowering the FAR generated by the Doswell technique alone. For example, satellite imagery occasionally shows stratiform frontal situations in which diurnal heating is reduced by cloudiness, and the likelihood of severe becomes significantly less. A catalog of such factors will be assembled for presentation in some organized format, say in the form of an expert system.

Another way of increasing the CSI being considered is in improving the POD. For example, marginal "Doswell days" can be clarified when some unexpected, yet important, ingredient is identified via another data source (e.g., an outflow boundary on satellite, or an easterly surge of upslope flow sensed, say, by a nearby profiler site). Such possibilities offer a plethora of mesoscale research opportunities.

Acknowledgments. The authors would like to acknowledge the diligent work by Mr. Tye Parzybok who played the part of the "nonspecialized forecaster" for this study. We would also like to acknowledge many helpful comments by Dr. Charles Doswell (NSSL, Norman, Oklahoma). A portion of this research was supported by the Cooperative Institute for Research in the Atmosphere at Colorado State University under NOAA Grant NA-85-RAH-05045. The authors also wish to thank Mrs. Debbie Eckdahl for typing the manuscript.

REFERENCES

Donaldson, R. J., Jr., R. M. Dyer and M. J. Kraus, 1975: An objective evaluator of techniques for predicting severe weather events. Preprints: *9th Conf. on Severe Local Storms,* 21–23 October, Norman, 321–326.

Doswell, C. A., 1980: Synoptic-scale environments associated with High Plains severe thunderstorms. *Bull. Amer. Meteor. Soc.,* **61,** 1388–1400.

Henz, J. F., 1973: Characteristics of severe convective storms on Colorado's High Plains. Preprints: *8th Conf. on Severe Local Storms,* Denver, Amer. Meteor. Soc., 96–103.

Modahl, A. C., 1979: Low-level wind and moisture variations preceding and following hailstorms in northeast Colorado. *Mon. Wea. Rev.,* **107,** 442–450.

NOAA, 1979–88: *Storm Data.* Nat'l. Clim. Data Center, ISSN-0039-1972, Asheville, North Carolina.

Schultz, P., 1989: Relationships of several stability indices to convective weather events in northeast Colorado. *Wea. Forecasting,* **4,** 73–80.

Weaver, J. F., and N. J. Doesken, 1990: Recurrence probability—A different approach. *Weather,* **45, 9,** 333–339.

——, and J. J. Toth, 1990: The use of satellite imagery and surface pressure-gradient analysis modified for sloping terrain to analyze the mesoscale events preceding the severe hailstorms of 2 August 1986. *Wea. Forecasting,* **5,** 279–298.

Wetzel, P. J., and P. C. Sinclair, 1973: Moisture sources and flow patterns during the northeast Colorado hail season. Preprints: *8th Conf. on Severe Local Storms,* Denver, Amer. Meteor. Soc., 90–95.