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ANALYSIS OF SEVERAL ETA MODEL SEVERE WEATHER INDICES AND VARIABLES IN FORECASTING SEVERE WEATHER ACROSS THE HIGH PLAINS

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I. INTRODUCTION

Forecasting the onset of severe convective weather across the High Plains can be difficult. Topography differences from one end of a county warning area to the other can differ up to 5,000 feet. These topographical differences are not well handled by numerical weather prediction models (NWP) primarily due to insufficient horizontal resolution. The inability of NWP to accurately represent topography impacts the model depiction of the location and depth of low level moisture, an important contributor to convective instability. Convective Available Potential Energy (CAPE) is a measure of the amount of energy available for convection. The computation of CAPE is very sensitive to the amount of low level moisture (Bluestein 1993), so model forecasted CAPE can be unrepresentative in areas with large topographical differences. Given this deficiency in model resolution of topography, other parameters may serve as a better tool in forecasting severe convective weather across the High Plains. This paper establishes a baseline of various indices and parameters that can be used to analyze and forecast the threat for severe convective weather. For this study, 679 severe weather reports were collected and compared to fields from the 12 UTC Eta model 12 hour forecast valid 00 UTC. These parameters, analyzed at a resolution of 1°C, include K-index, Total-Totals, 700 mb temperatures, 700 mb dewpoints, and 500 mb temperatures, parameters often analyzed for forecasting thunderstorms. This paper addresses their potential in forecasting severe thunderstorms using a study similar to Bonner (Bonner et al. 1971).

II. DATA AND METHODOLOGY

This study comprised of 679 severe convective weather events was analyzed during the year 2000 bounded by the areas in Fig. 1. These events were plotted from the SPC daily severe weather summary from 2100 UTC to 0300 UTC. This data includes tornadoes, large hail > 0.75 inches and severe wind gusts (> 50 kts). To record a parameter's performance, a plot of the Storm Prediction Center (SPC) severe weather summary was overlaid with the parameter from the 12 UTC Eta 12 hour forecast valid 00 UTC.

Data collected for this study began in April 2000 and ended in early November 2000. The dataset was comprised primarily of data in which severe or tornadic thunderstorms were reported with a rather limited null data set. The area of study was centered on the Goodland county warning area (CWA) and included those CWA's adjacent to it.

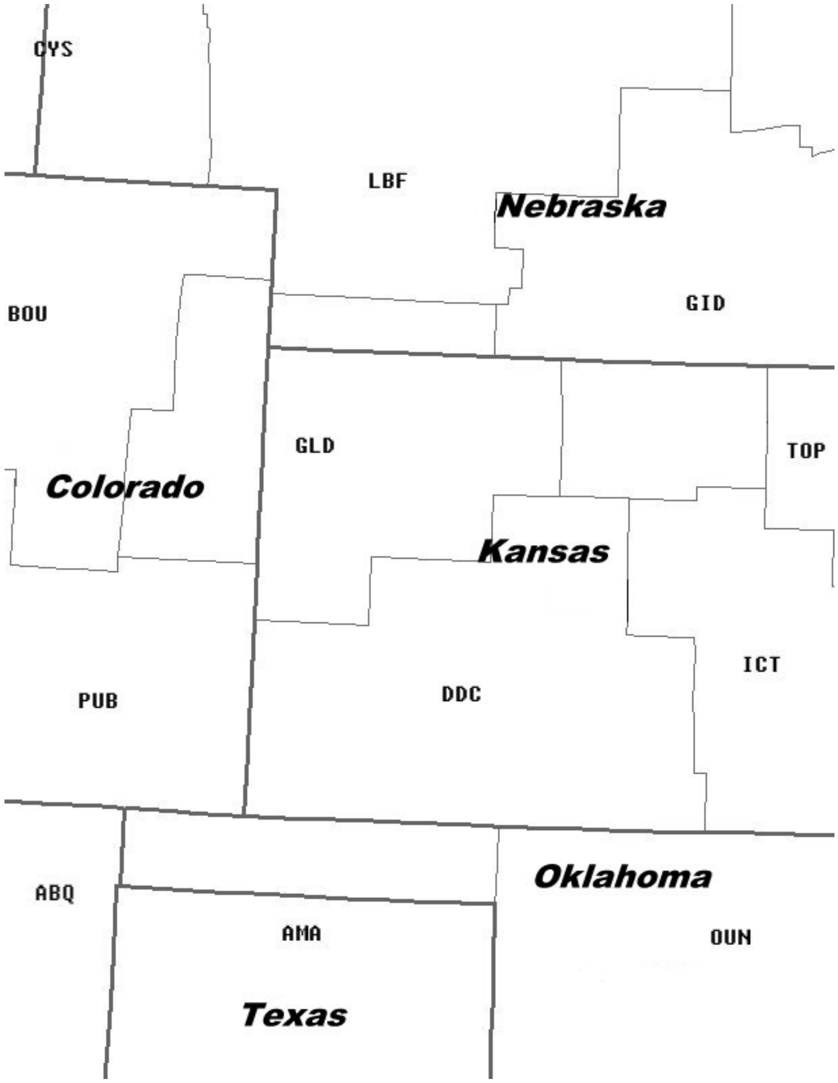

Figure 1: Study Boundaries.

A. *K-index*

The K-index (KI) is the sum of the 850 mb temperature and the 850 mb dewpoint minus the temperature-dewpoint spread at 700 mb and minus the 500 mb temperature (George 1960). It can be expressed as
$KI = T_{850} + T_{d,850} - (T_{700} - T_{d,700}) - T_{500}$.

Table 1 expresses various K-index values and corresponding probabilities of thunderstorms.

TABLE 1

Comparison of K-Index and Corresponding Probabilities of Thunderstorms	
K-Index	**Storm Probability**
<15	0%
15-20	<20%
21-25	20-40%
26-30	40-60%
31-35	60-80%
36-40	80-90%
>40	near 100%

Bonner (Bonner et al. 1971) noted that of the predictors studied, the one showing the highest correlation coefficient with echo occurrence was the K-index.

The distribution of 679 severe weather reports collected during the study is shown in Fig. 2. Approximately 82% fell where the forecast K-index value was greater than 30. Approximately two thirds (66%) of the severe weather reports were reported when the forecast K-index values were 35 or greater. Only 25% of the severe weather reports were with a K-index value of 40 or more (Fig. 3).

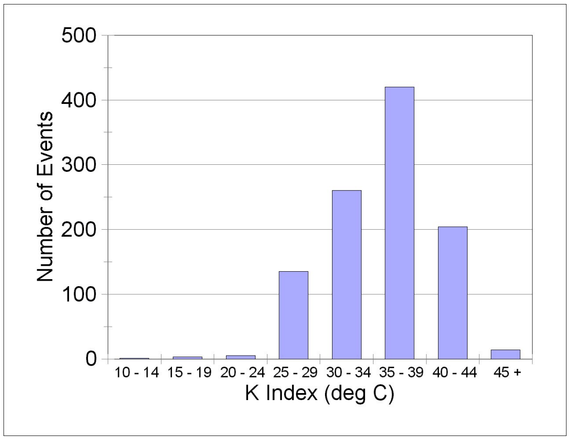

Figure 2: Relationship between number of severe storms and K Index.

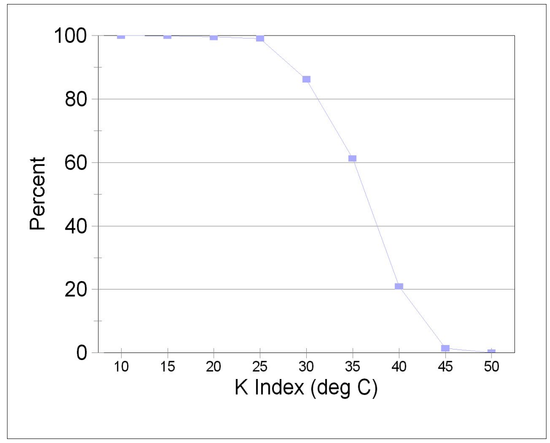

Figure 3: Percent of severe storms occurring at or below a given K Index.

B. *Total-Totals*

The Total-Totals Index (TT) consists of two components: Vertical Totals (VT) and Cross Totals (CT). VT represents static stability using the temperature difference between 850 (T_{850}) and 500 mb (T_{500}). The CT is computed similarly to the VT but uses 850 mb dewpoint ($T_{d,850}$) rather than 850 mb temperature. As a result, TT accounts for both static stability and 850 mb moisture (Miller 1972). It is defined as:

$VT = T_{850} - T_{500}$
$CT = T_{d,850} - T_{500}$
$TT = VT + CT = T_{850} + T_{d850} - 2T_{500}$

Total-Totals values < 50 suggest weak instability and that thunderstorms are possible while values of 50 to 55 indicate moderate instability and that thunderstorms are more likely with some severe. Total-Totals values > 55 indicate strong instability and that severe thunderstorms are likely. Miller (Miller 1972) found that "the TT is more reliable single predictor of severe activity in both warm- and cold-air situations. However, Total-Totals must be used with careful attention to either the Cross Totals or the low-level moisture, since it is possible to have large Total-Totals due to the temperature lapse rate with little supporting low-level moisture".

Bonner (Bonner et al. 1971) summarized that the Total-Totals was the best single predictor showing the highest linear correlation with "intense" convection.

The distribution of severe weather reports compared to the 12 hour Eta forecast of TT is given in Fig. 4. Approximately 9% of the severe weather reports occurred when the forecast Total-Totals was less than 50. However, as the Total-Totals increased, so did the number of severe weather reports. Approximately 91% of the reports occurred with forecast Total-Totals of 50 or greater. Just under half of the reports (44%) occurred with forecast values at or above 55 (Fig. 5). These values suggest to the forecaster that the threat of severe weather increases as the Total-Totals increases and that further examination of weather data is needed to substantiate the increased severe weather threat.

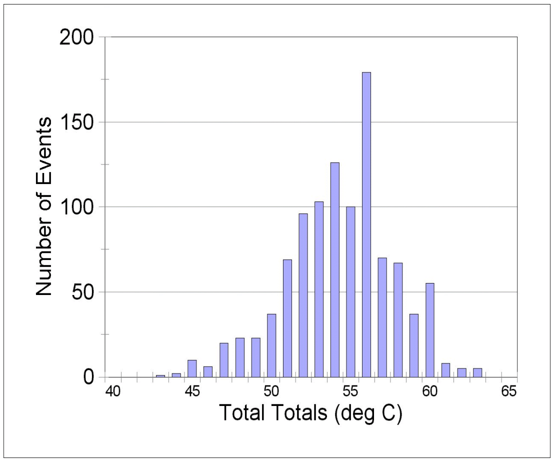

Figure 4: Relationship between number of severe storms and Total Totals.

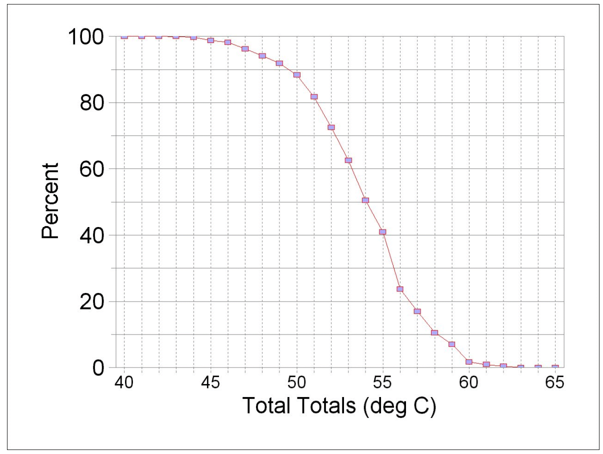

Figure 5: Percent of severe storms occurring at or below a given Total Totals.

C. *700 mb temperature*

700 mb temperature is often used to estimate the cap strength, or the inhibition of convective initiation. Miller (Miller 1972) found that during summer months the more significant storms appear to form north and northeast of the 10°C to 14°C isotherms at 700 mb.

The distribution of severe weather reports occurring within 3 hours of the 12 hour Eta forecast of 700 mb temperature is shown in Fig. 6. Of the 679 reports used for this study, 67% occurred when forecast temperatures were 10°C or greater and 29% when the temperature was 13°C or greater (Fig. 7). It should also be noted that the number of severe weather events increases sharply once the forecast temperature reaches 9°C. This forecast temperature should not be considered a lower bound.

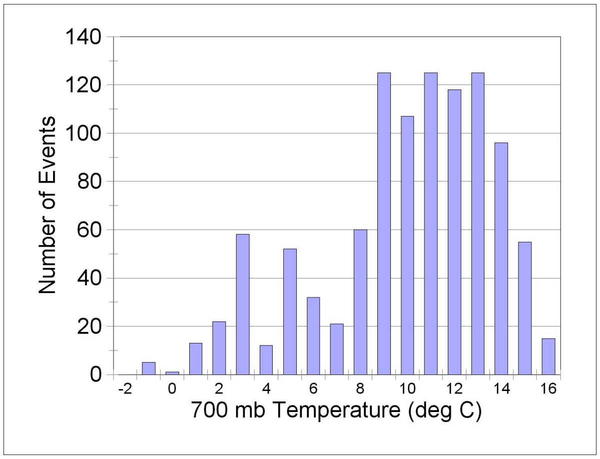

Figure 6: Relationship between number of severe storms and 700 mb temperatures.

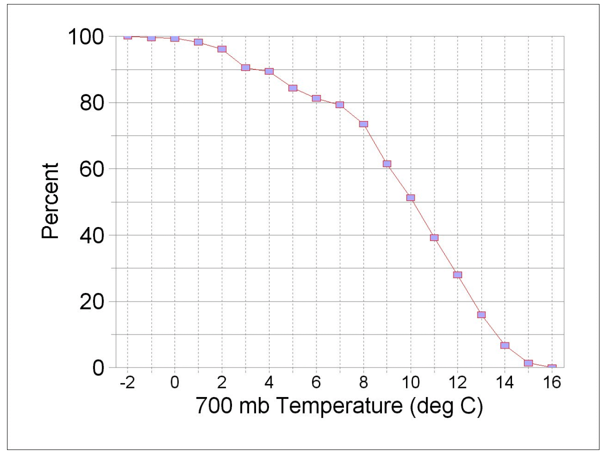

Figure 7: Percent of severe storms occurring at or below a given 700 mb temperature.

D. *700 mb dewpoint*

Bonner (Bonner et al. 1971) applied a technique using output from numerical models to predict severe local storms and thunderstorms. Their results indicated the six predictors showing highest individual correlation coefficients with echo occurrence were the moisture parameters. The highest correlations occur with dew point or relative humidity at 700 mb. Miller (Miller 1972) reported that in routine operations we consider 50% relative humidity, dewpoints of less than 0 degrees C, or a temperature-dewpoint spread of more than 6°C at 700 mb as “dry”.

The distribution of severe weather reports compared to 12 hour Eta forecasts of 700 mb dewpoint are shown in Fig. 9. Additionally, 94% of the reports occurred when the forecast 700 mb dewpoint was greater than or equal to -5°C with 75% of reports occurring with values greater than or equal to 0°C (Fig. 10). However, once the 700 mb dewpoint was greater than or equal to 5°C, the number of reports fell sharply to 28%. The steady rise in the number of severe weather events and increase in 700 mb dewpoint temperature may follow a similar theme to the 700 mb temperature.

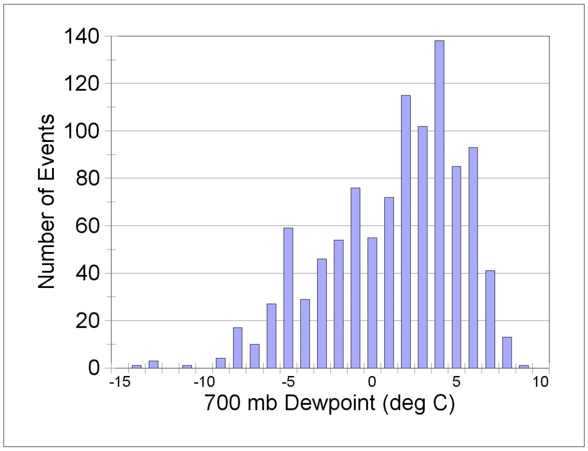

Figure 8: Relationship between number of severe storms and 700 mb dewpoint.

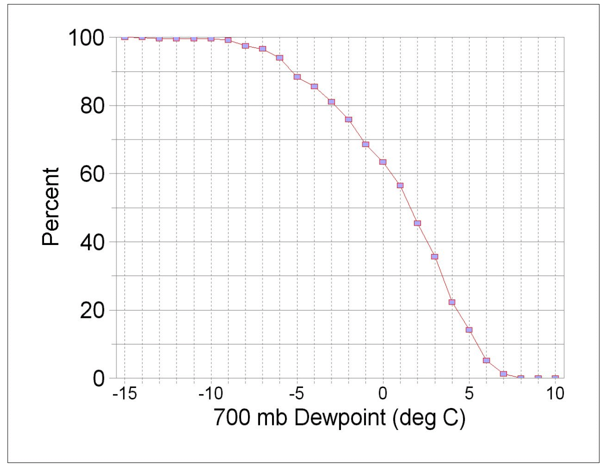

Figure 9:Percent of severe storms occurring at or below a given 700 mb dewpoint.

E. *500 mb temperature*

Bonner (Bonner et al. 1971) concluded that of the correlation coefficients that reflect both the ability of the model to predict a particular variable and its physical relationship with convective activity, 500 mb temperatures ranked fifth. Miller (Miller 1972) wrote that “significant isotherms at 500 mb are a critical or threshold value of temperature at that level for moderate to severe thunderstorm activity during certain seasons of the year.” Critical values used by the Air Force Global Weather Center (AWGWC) are as follows: December, January, February (-16°C); March, April, October, November (-14°C); May, June (-12°C); and July, August, September (-10°C).

Miller (Miller 1972) noted “temperatures warmer than -7°C are infrequently associated with severe weather and usually permit only isolated occurrences of strong gusty surface winds and heavy rain.”

The distribution of severe weather reports compared to the 12 hour Eta forecasts of 500 mb temperature are shown in Fig. 10. In this study, 97% of the 679 reports occurred when 500 mb temperatures ranged from -5°C to -15°C while from -10°C to -15°C the percentages fell below half (43%)(Fig. 11).

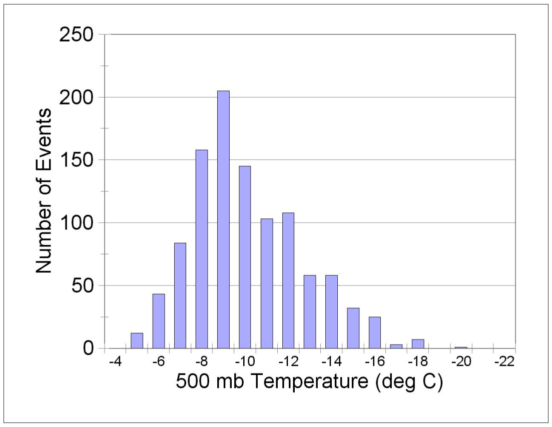

Figure 10: Relationship between number of severe storms and 500 mb temperature.

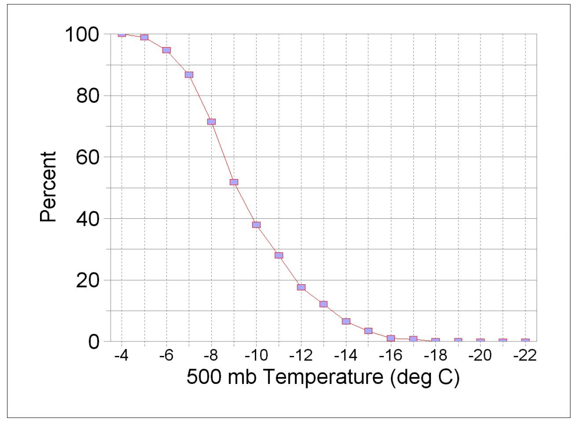

Figure 11: Percent of severe storms occurring at or below a given 500 mb temperature.

III. June 13 2000 Severe Weather Outbreak

Upper air analysis from 1200 UTC 13 June 2000 indicated a broad 500 mb trough (Fig. 12) centered along the lee side of the Rockies. At 250 mb a 95 knot jet maximum was approaching the base of the trough (Fig. 13). At 850 mb (Fig 14) and 700 mb (Fig. 15) the base of the trough was also observed with 700 mb temperatures in the study area ranging from 11°C at KLBF (North Platte, NE) to 14°C at KDDC (Dodge City, KS). An 850 mb southwest low level wind maximum was observed at KDDC with a sharp gradient in moisture being confined to the central and eastern research area.

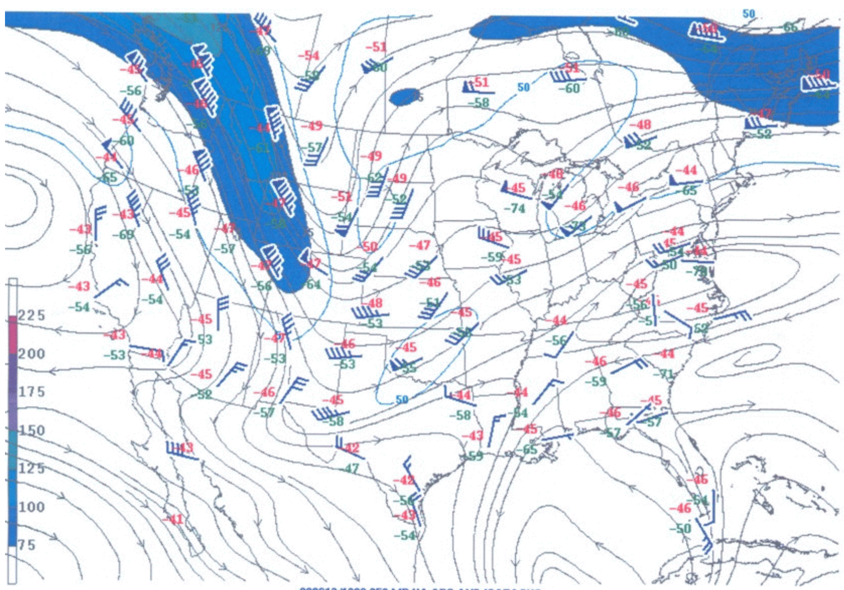

Figure 12: 250 mb 1200 UTC 13 June 2000.

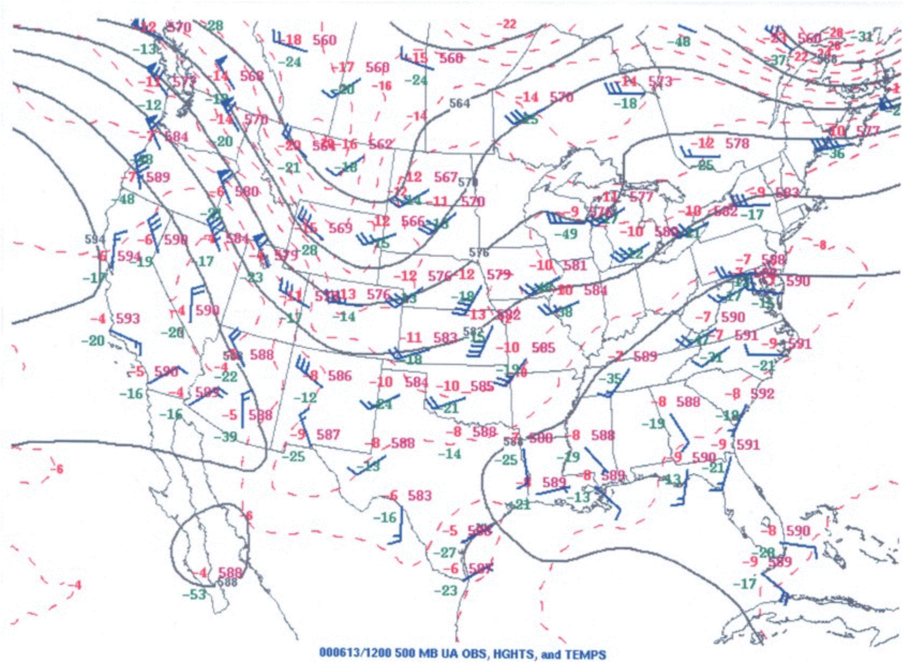

Figure 13: 500 mb 1200 UTC 13 June 2000.

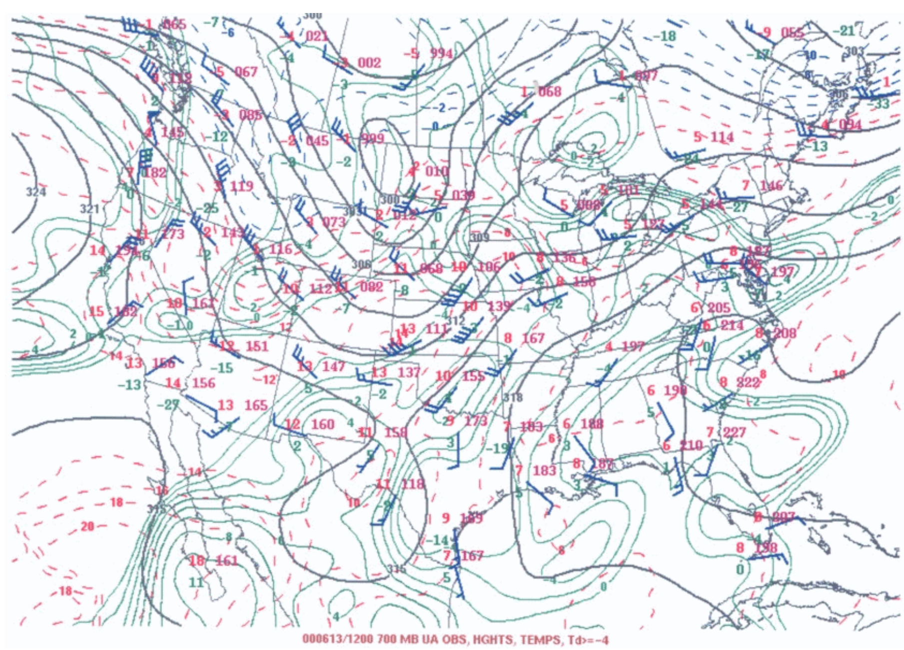

Figure 14: 700 mb 1200 UTC 13 June 2000.

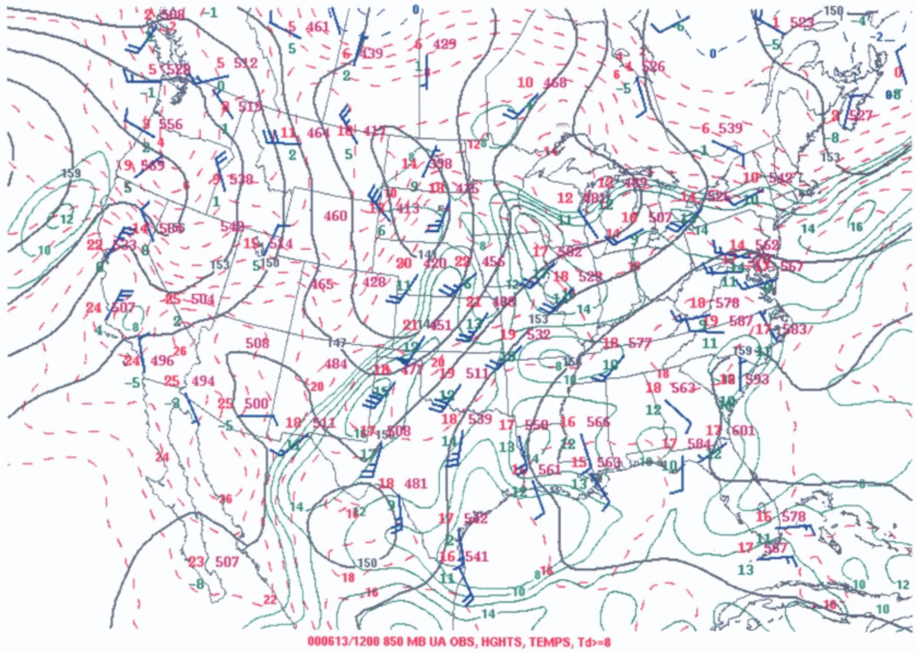

Figure 15: 850 mb 1200 UTC 13 June 2000.

Eta 12 hour forecasts valid 0000 UTC 14 June 2000 indicated an axis of Total-Totals (Fig. 16) and K-Indices (Fig. 17) nearly overlaid on top of each other with values of 54-57 and 40 respectively. These values were strongly supportive of severe thunderstorm activity provided that there was no cap and a trigger was forecast. 700 mb temperatures (Fig. 18) were forecast to range from 7°C to 13°C (northeast to southwest); supportive of a lack of significant warm air aloft and cap. 700 mb dewpoints (Fig. 19) ranged from 2°C to 4°C and 500 mb temperatures (Fig. 20) were forecast to be in the -8°C to -10°C range. These values were also supportive of severe thunderstorm potential with the area under the highest probability from east-central Kansas to the Texas panhandle.

Severe thunderstorms did develop during the afternoon and evening hours as seen by the various indices and parameters overlaid with the SPC reports from 1200 UTC 14 June 2000.

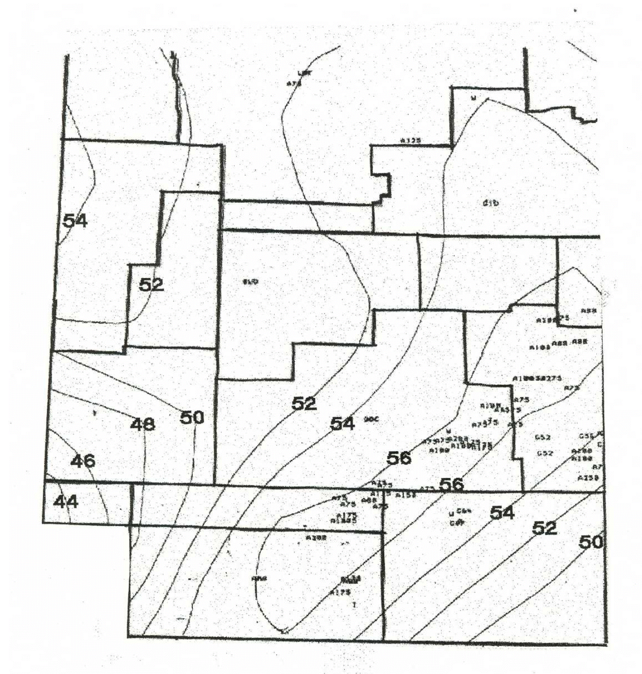

Figure 16: Total Totals 0000 UTC 14 June 2000.

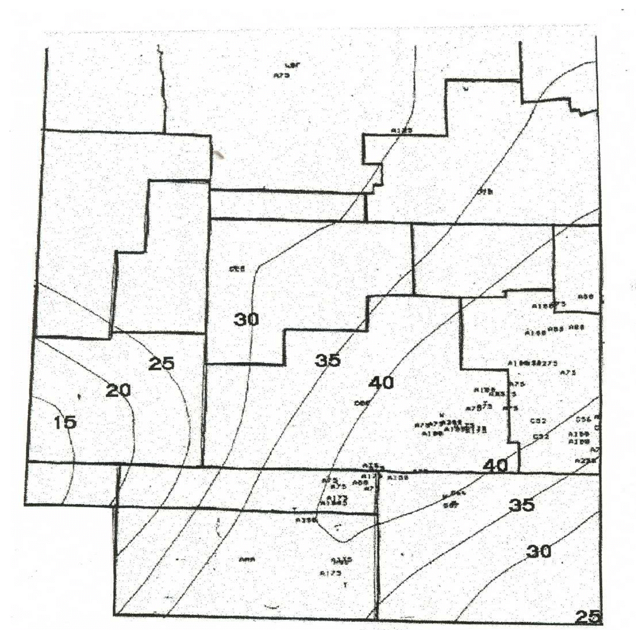

Figure 17: K Index 0000 UTC 14 June 2000.

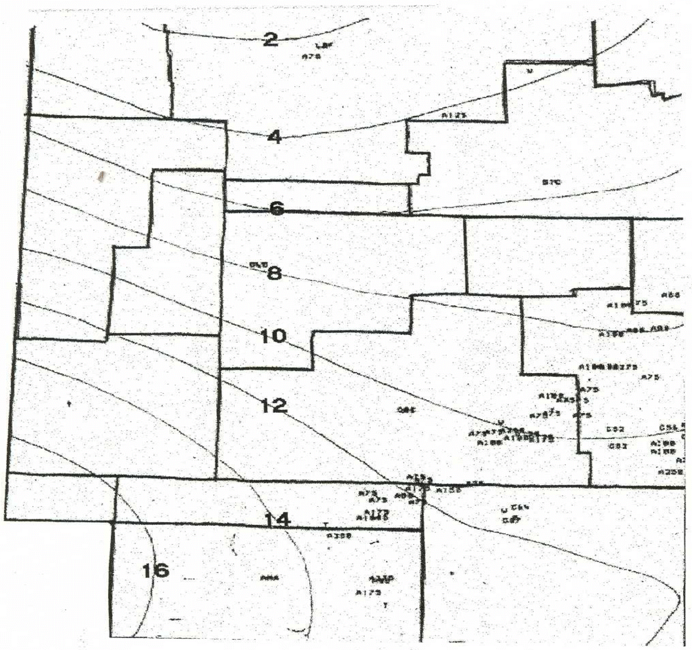

Figure 18: 700 mb temperatures 0000 UTC 14 June 2000.

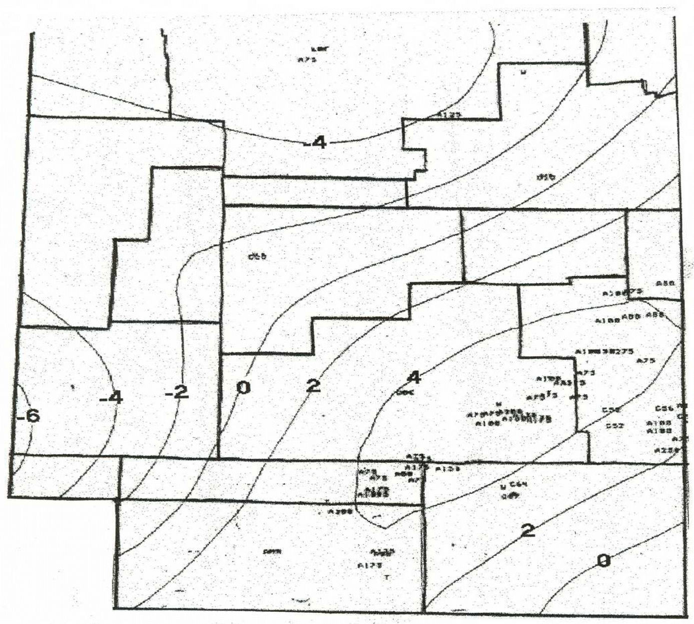

Figure 19: 700 mb dewpoints 0000 UTC 14 June 2000.

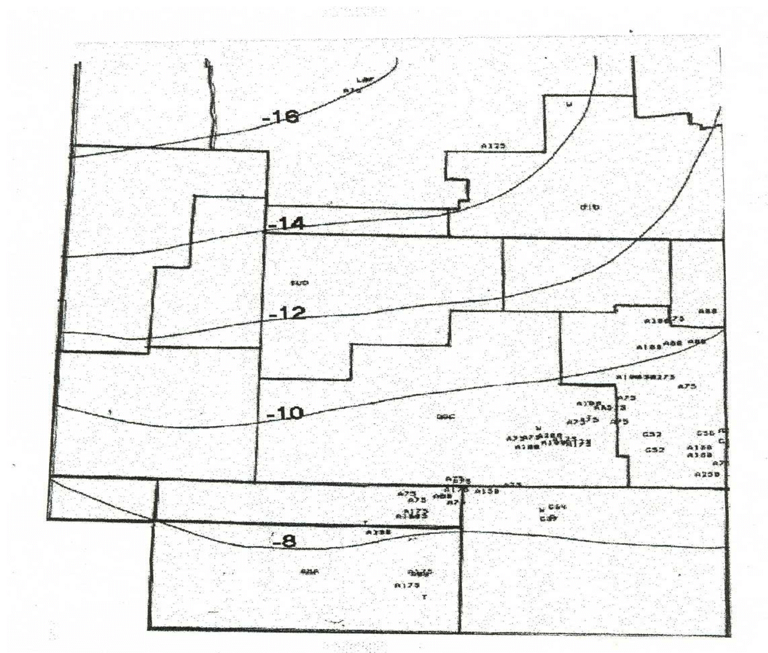

Figure 20: 500 mb temperatures 0000 UTC 14 June 2000.

IV. CONCLUSIONS

Although the parameters used in this study were analyzed for thunderstorm potential by Bonner (Bonner et al. 1971), this study analyzes the data in an effort to forecast the onset and areal extent of severe thunderstorms. With the wide range in topography and computer model resolution, forecasted CAPE can be underdone and not reliable, primarily because of the difficulty in properly resolving the amount of low level moisture. For this reason, other parameters may serve as a better tool in forecasting severe weather across the High Plains.

Of the 679 reports collected during the study, approximately 82% fell where the K-index values were greater than 30 and approximately two thirds (66%) were reported when the forecast K-index values were 35 or greater. Taking these values into consideration, one could then overlay the Total-Totals forecast graphic. With approximately 91% of the severe weather reports occurring when forecast Total-Totals were 50 or greater and nearly half of the reports (44%) occurring when values were at or above 55, one could quickly discern the area most likely to have potential for severe thunderstorm activity. However, one must now assess the potential for capping either by limitations in moisture or warm air aloft. In this study, 67% of severe weather reports occurred when forecast 700 mb temperatures were 10°C or greater and 29% when the temperature was 13°C or greater. The study found severe convective weather reports occurring with forecast temperatures as high as 14°C to 16°C, contrary to values Patrick (Patrick 1990) cited as a good value to look for when evaluating cap potential. Three quarters (75%) of the severe weather events reported occurred when 700 mb dewpoints were 0°C or greater. Lastly, Miller (Miller 1972) reported that 500 mb temperatures warmer than -7°C are infrequently associated with severe weather and usually permit only isolated occurrences of strong gusty surface winds and heavy rain. This study also supports those findings with nearly 1% of the 679 severe weather reports occurring when the forecast 500 mb temperature was warmer than -7°C.

Often, the first hint the forecaster gets that the atmosphere may be conducive to convection comes from the examination of stability indices such as the lifted index, K index, total totals, and surface based cross totals (Bluestein 1993; Davies 1988). These variables can be used in conjunction with the Storm Prediction Center's severe weather outlooks, but on a localized scale. Although these parameters should not be used alone, they could be used as a quick check for the potential of severe thunderstorm activity by assessing forecast instability, moisture, and capping potential above the surface. This quick check can aid in focusing where and when the highest potential for severe thunderstorms may occur and work in concert with other datasets to determine the type of activity expected.

The results of this study have been incorporated operationally into the WFO Goodland severe weather checklist used by the forecast staff when assessing severe weather potential. Although the parameters are already in the checklist, this study emphasizes localized results and those values can be used more accurately.

V. ACKNOWLEDGEMENTS

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