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AN EXAMINATION OF A DOWNBURST AND TWO MICROBURSTS IN THE EASTERN PLAINS WITH A VERY WARM MID-LEVEL ENVIRONMENT

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1. Introduction

It has long been suggested that in the eastern part of the Great Plains the chances for thunderstorms become small with a 700 mb temperature greater than +10°C. It has also been suggested that the areas of thunderstorms often occur on the cool side of the 700 mb +10°C isotherm (Fig. 1). Since generated 700 mb temperature forecasts are not available, a field forecaster relies on 576 meter 1000-500 mb thickness line which closely corresponds to the 700 mb +10°C isotherm (Fig. 2). Schaefer (1986) mentions this rule and also notes that in forecasting nocturnal Mesoscale Convective Complex (MCC) events that a 700 mb temperature greater than +12°C suppresses organized convection. This 700 mb isotherm rule of thumb for the Eastern Plains would not have the same application in the Western Plains due to the higher surface elevations.

Rules of thumb are convenient empirical tools that can be of great use to a forecaster "under the gun." There are scientifically based reasons why the rules work. Sometimes, however, they will fail. Doswell (1986) has pointed out that it is the responsibility of all meteorologists to not only be empiricists, but also to understand the foundations of the rule. Otherwise, it would be impossible to know in advance when the rule will fail.

The +10 to +12 degrees 700 mb temperature rule works because when the mid-level becomes very warm stronger large scale forcing is usually required in order to initiate thunderstorms. Stability and the presence of inversions in the plotted soundings must also be considered.

The author has found the "+10 rule" very useful and often has helped me to locate the greatest probability of thunderstorms. The author has also observed that when the rule failed and thunderstorms do occur with very warm mid-level temperatures in the Omaha area, that downbursts or microbursts are possible. One example of when the rule failed was July 15, 1988 when strong forcing overcame 700 mb temperatures of +12°C or better. The strong forcing mechanisms were a Mesoscale Vortex Center (MVC) (as described by Johnston (1982)), along with differential heating and moisture convergence. The MVC developed with a flash flood producing MCC the previous night in southwest Nebraska and moved into east

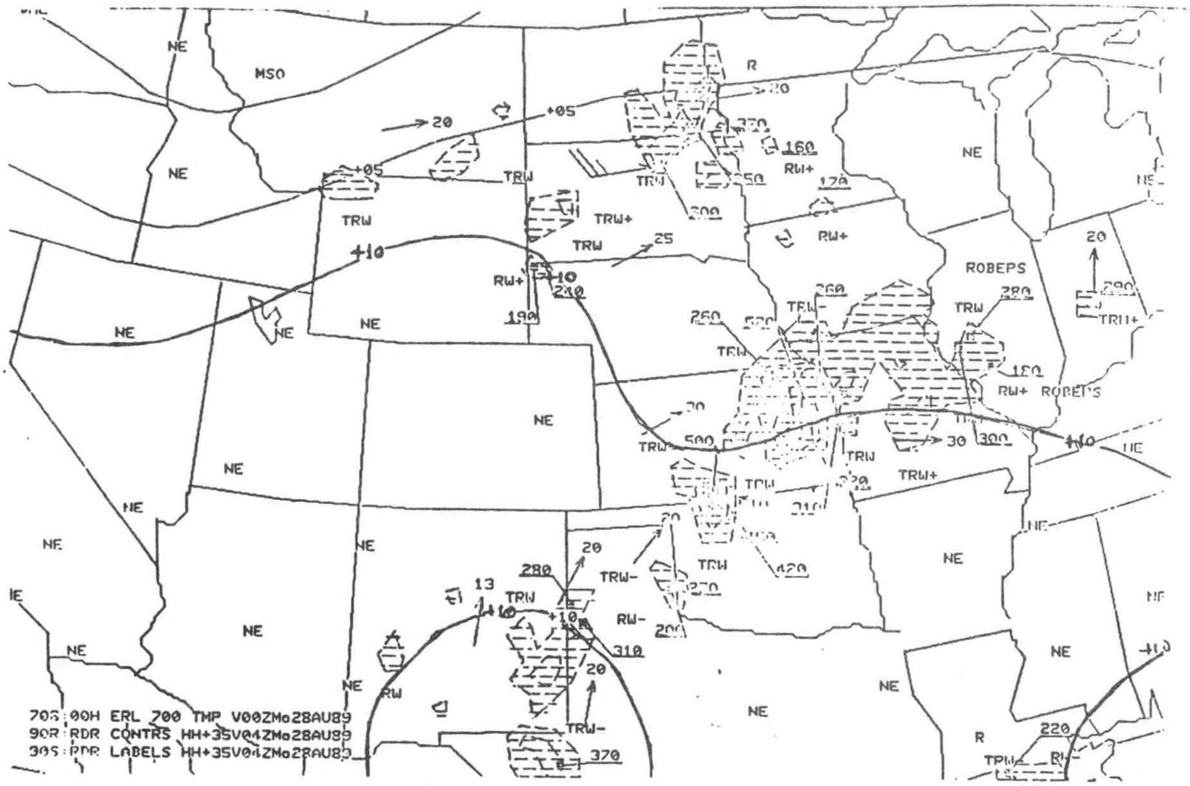

Figure 1. Radar analysis for 04Z and 700 mb temperature analysis for 00Z, August 28, 1989.

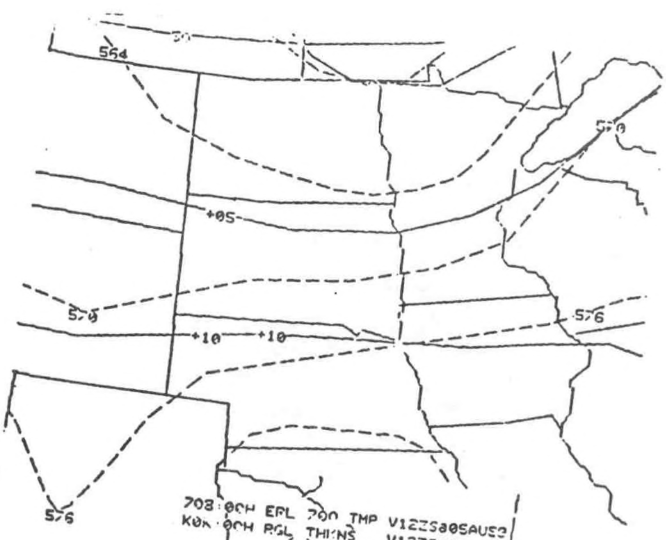

Figure 2. Thickness (dashed lines) and 700 mb temperature (solid lines) analysis for 12Z, August 5, 1989.

central Nebraska in the afternoon. The resulting severe thunderstorm produced a tornado at Council Bluffs Iowa along with several downbursts and microbursts.

This paper will investigate the situation in which thunderstorms occur with 700 mb temperatures greater than +10°C or +12°C. Forecasters should be alert to the possibility of downbursts or microbursts under such conditions.

2. Case Studies

A. Case I - A Major Downburst Event in Northeast Nebraska

During the pre-dawn hours of August 5, 1989 thunderstorms developed in north central Nebraska. The 00Z and 12Z August 5, 1989 Omaha, Nebraska (OMA) soundings showed 700 mb temperatures of +12°C. The +10°C 700 mb isotherm extended east-west across northern Nebraska. The high based thunderstorms developed in an area of divergence aloft in the right rear quadrant of a jet max. Also, there was enough mid-level cold advection to break the capping effect of the warm mid-level temperatures (see Fig. 3). A violent thunderstorm produced widespread damage due to downbursts across northeast Nebraska extending to just north of Omaha. Winds gusted to 81 mph when the thunderstorms were in the Norfolk, Nebraska (OFK) area. The WSFO at Omaha reported wind gusts of 55 mph with the passage of the outflow boundary.

Thus, with this case there was strong forcing with a warm mid-level environment, and although low level moisture was not lacking (a 12°C dew point at 850 mb) on the 12Z August 5, 1989 OMA sounding (see Fig. 4), the warm lapse rate below the high cumulonimbus (CB) cloud base allowed entrained air, cooled by evaporation, to become extremely negatively buoyant.

In light of this case in which strong forcing was necessary for thunderstorm production due to the warm mid-level environment, it can be seen that even with a high low level mean mixing ratio the thunderstorms on the morning of August 5 were high based. Note that the thunderstorms did remain near the +10°C, and that in the warmer air to the south no thunderstorms occurred. The strong outflow boundary generated by the downbursts moved well south of the parent thunderstorms, which remained north of the +12°C 700 mb isotherm. The thunderstorms favored the area along the +10°C isotherm at 700 mb.

So, the "rules of thumb" worked in this case. But, it is suggested that the "rule" be expanded so that, if thunderstorms do occur with these warm mid-level temperatures, forecasters are aware of the potential for downbursts and microbursts.

The next two cases are an examination of warm mid-level environments in which microbursts occurred in the WSFO Omaha county warning area. In these cases, not only will the forcing mechanism be examined, but also the thermodynamics.

From Haltiner and Martin's Dynamical and Physical Meteorology

$$d\,(w\,/2) = -R_d\,(T_v' - T_v)\,d(\ln p) \qquad (1)$$

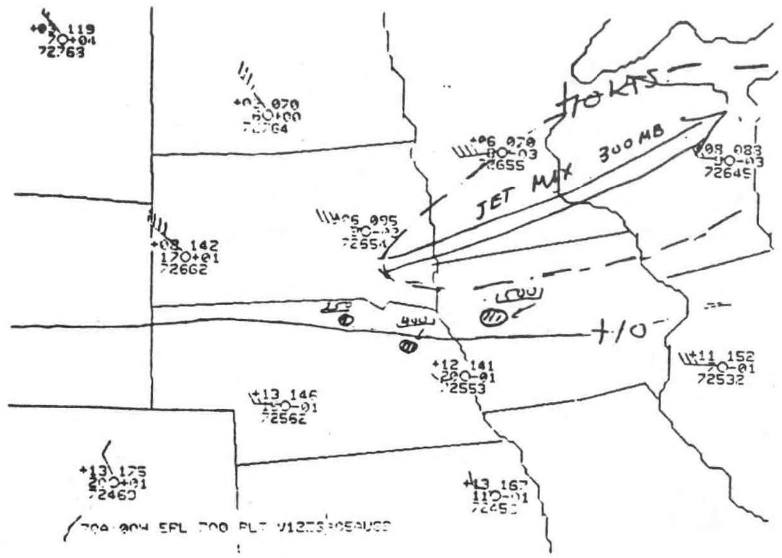

Figure 3. 12Z August 5, 1989 300 jet overlaid on the 700 mb analysis.

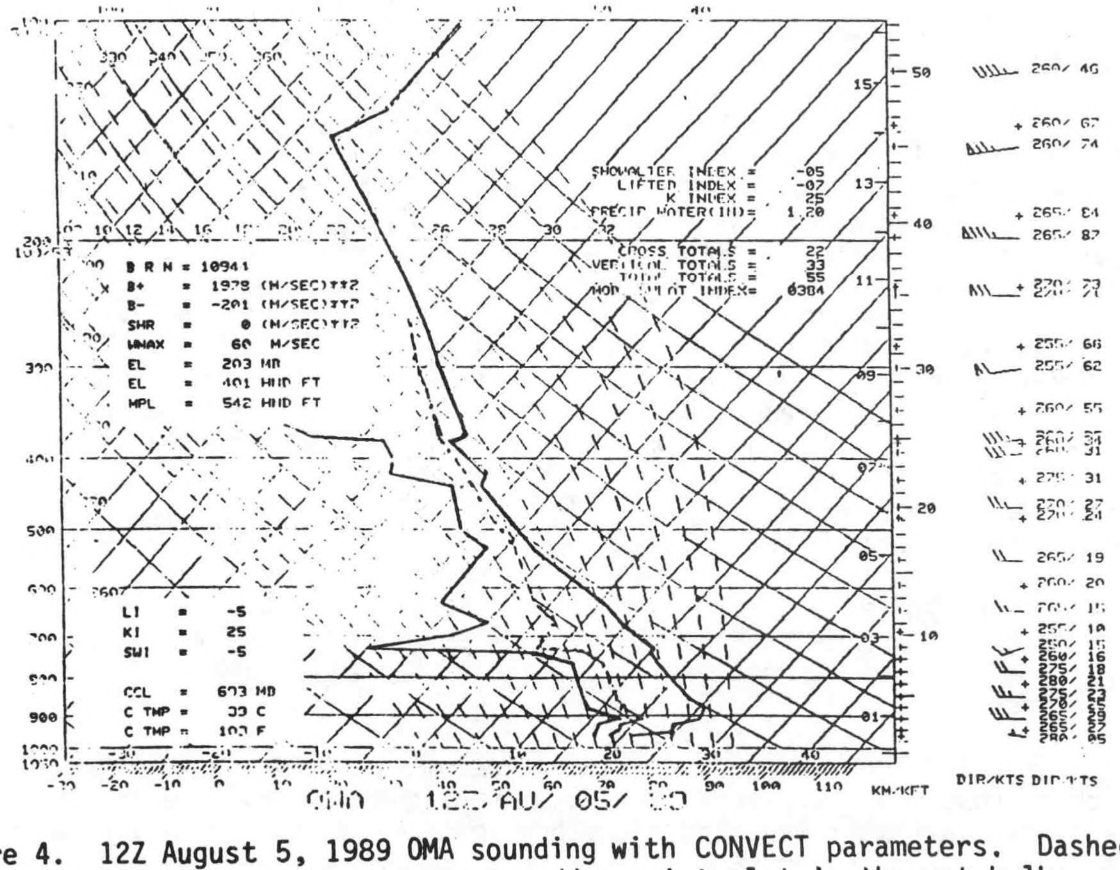

Figure 4. 12Z August 5, 1989 OMA sounding with CONVECT parameters. Dashed line between the temperature/dew point plot is the wet bulb temperature.

where

w = vertical velocity
R_d = the gas constant for dry air
T_v'= the virtual temperature of a parcel
T_v = the environment
p = Pressure virtual temperature.

The equation shows that the change in the vertical velocity of an accelerated parcel is a function of the difference between the virtual temperature of the environment (T_v) and the parcel (T_v'). The parcel method is a familiar analysis tool and energy for the updraft can be determined from the positive area on the skew-T after lifting a parcel through saturation and then along a moist adiabat through the equilibrium point, usually above the troposphere in strong storms.

Here in this paper the concern is the acceleration of a parcel of air that has been cooled by evaporative cooling below the high based thunderstorm in the below cloud base environment. The source of the entrained air that is accelerated downward to cause downbursts or microbursts can either be air cooled at or below the cloud base, or as Kessler (1985) suggests, from areas above the base. Downbursts and microbursts that occur in low based thunderstorms with very moist low layers most likely originate well up into the cloud layer where some dry air is entrained, as stated by Kessler (1985). Kessler based this fact on the evidence of the low wet bulb temperatures observed beneath severe thunderstorms. Kessler pointed out that negatively buoyant air will descend at the moist adiabatic lapse rate as long as there is enough precipitation to keep the descending air saturated. Fujita and Black (1986) studied the Small Severe Thunderstorm (SST) and pointed out that the mid-level dry air can be drawn into the descending current easily by virtue of the small cloud diameter. Darkow and McCann (1975) show that the relative wind flow from 121 severe thunderstorms was at a minimum at this level, suggesting that this is the most likely level for injection of environmental air into the storm. If, however, the entire liquid content of the descending parcel is evaporated (as is the case of some microbursts from high based thunderstorms) the descent would be dry adiabatic.

In the two cases of microbursts that are examined here, the soundings are not of a pre-storm environment, but rather of the microburst environment beneath high based cumulonimbus. It was assumed that the air near the cloud base is cooled to the mean wet bulb temperature, then descended moist adiabatically for a short time with the parcel then descending and warming dry adiabatically. The energy of the negative parcel is proportional to the areas shown on the curves of Figures 5 and 6.

The vertical velocity profile of descending parcel can be constructed using the equation

$$\frac{dw}{dt} \approx w\frac{\partial w}{\partial z} = \frac{\partial(w^2/2)}{\partial z} = g\,(T_v'-T_v)/(T_v) \tag{2}$$

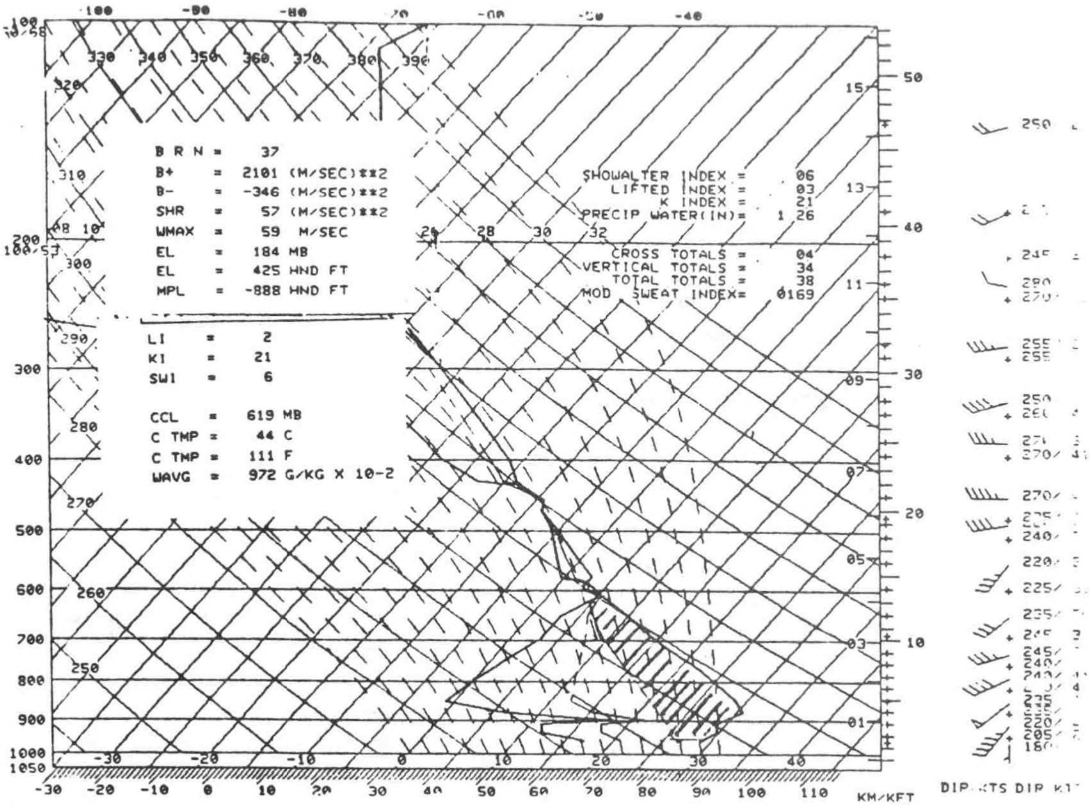

Figure 5. 12Z July 14, 1980 OMA sounding with CONVECT parameters and negative area for estimating microburst winds.

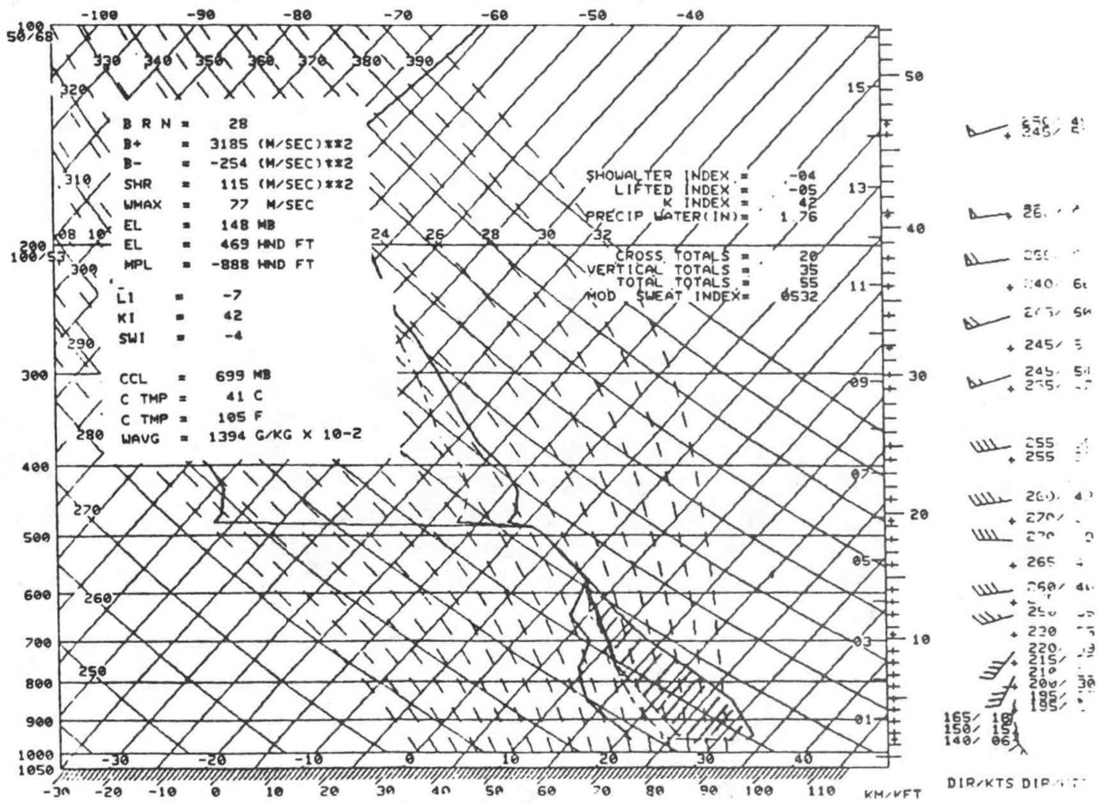

Figure 6. 00Z July 16, 1980 OMA sounding with CONVECT parameters and negative area for estimating microburst winds.

where w = vertical velocity m/sec
g = 9.8 m/sec^2
T_v = ^oK

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$$\Delta (w^2/2) = g(T_v'-T_v)/(T_v)\ \Delta Z \qquad (3)$$

using Δz = .5 km and assuming w=0 at cloud base and w_{sfc} diverges out becoming a surface horizontal velocity. The vertical velocity (i.e., w_{sfc}) can be computed by adding each Δw computed for each .5 km below the cloud base.

From the equation it can be seen that having a deep layer below the cloud base contributes to a stronger w_{sfc}. Also, the warmer the environment the greater the negative buoyancy of the parcel. Finally, the lower the wet bulb temperature of the entrained air the greater the acceleration of the parcel downward.

B. Case II - July 14, 1200Z

Although the 700 mb temperature at 1200Z (Fig. 5) from the OMA sounding was a very warm 14.8^{o}C, there were widely scattered small thunderstorms in the Omaha local area. The sounding indicated a cloud base of 14,000 ft (4.3 km). With such a warm T_v and a low T_v', due to the low wet bulb temperature of the layer, the stage was set for the microburst. At 10Z Valley, Nebraska, just northwest of Omaha, reported a 90 mph wind gust, damaging six homes and a factory.

Another interesting feature concerning the atmospheric conditions the morning of this microburst was the possible contribution of downward mixed momentum of the low level jet. (Note in Fig. 5 the 50 kt SW wind 4 to 5 thousand feet.) Brown et al. (1982) suggest that the microburst in high based cumulonimbus clouds was a negligible factor, and that the main contributor was the divergence forced by the downdraft impinging on the surface of the earth.

Calculations of the vertical velocity attained near the ground using equation (3) for this sounding suggest that a damaging microburst could occur simply from the thermodynamics. Assuming that the vertical velocity .5 km above the ground is converted at the surface to a horizontal component, a wind speed of 85 mph was calculated. This compared well with the observed microburst at Valley, Nebraska.

C. Case III - July 16, 1980 0315Z

On the evening of July 15 at 10:15 p.m. CDT, a microburst with winds estimated at 100 mph caused severe damage to the town of Silver City, Iowa, 20 miles southeast of Omaha. Boards were blown through the sides of houses and a huge ammonia tank was hurled several yards. A survey of the damaged area verified a narrow band of straight line wind caused the damage. Rain with the microburst was reported to be hard for just a brief time.

Looking at the 00Z OMA sounding (Fig. 6) note that the 700 mb temperature was 13.4^{o}C. A high cloud base of 15,000 ft (4.6 km) was indicated, and there were widely scattered thunderstorms in the area. Although the below cloud base environment was moist, the warm environment temperature and the high thunderstorm base allowed a large negative buoyancy area. Calculations indicated a potential surface wind gust of 77 mph. It was also noted that the cells in the Mills County area during the evening were small, placing this storm in the class of an SST, as was the storm in Case II.

3. Summary and Conclusion

A rule of thumb in the eastern part of the Plains is that the chance of thunderstorms decreases significantly when the 700 mb temperature is above +10^{o}C, and especially so at +12^{o}C or better. Often organized thunderstorm areas are found to the cold side of the +10^{o}C isotherm. For forecast purposes, the +10^{o}C isotherm at 700 mb corresponds closely to the 576 1000-500 mb thickness contour.

These rules of thumb, like all others, do not always work. Sometimes large scale forcing is strong enough to overcome the capping effect of the warm mid-levels. A thorough mesoscale analysis and use of the CONVECT AFOS Applications program (Stone, 1986) can help in determining when the rule will work or not work. But as a hypothesis, once thunderstorms develop in the Eastern Plains with these very warm mid-level temperatures, the potential for damaging downbursts and microbursts is enhanced. Theoretical values for computing a downburst vertical velocity profile can be easily derived using parameters obtained from the sounding and CONVECT output.

A scheme developed by McDonald (1976) for the Western Region computes the upper level stability index (UI) from the RAOBs and considers the 700 mb temperature/dew point spread. A parcel is lifted from 500 mb to the LCL then follows a saturation adiabat through 400 mb to 300 mb. UI is then expressed as,

$$UI = [T(400mb) - T(500mb\ parcel) + [T(300mb) - T(500\ mb\ parcel)$$

Using the nomogram in Figure 7 enter the 700 mb depression and the UI. The results are interpreted as: Area 1 is too moist for strong gusts; Area 2 is too stable for upper level thunderstorms; Area 3 yields gusts > 30 kts; and Area 4 yields gusts > 40 kts.

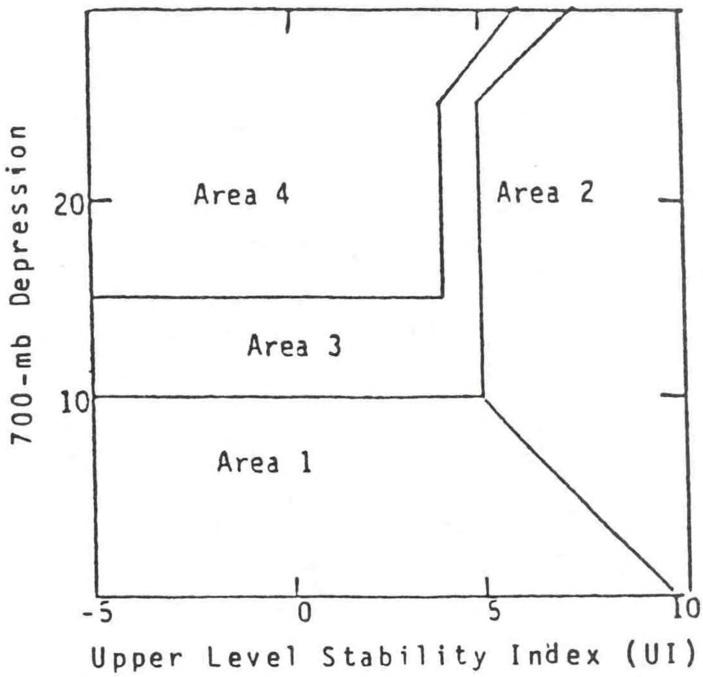

Figure 7. Nomogram for estimating gust potential based on the Upper level Stability Index (UI) and the 700 mb Depression.

Other offices could develop similar gust potential indices based on this scheme but lifting from 700 mb and using the depression at 850 mb.

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