1.2 SYNOPTIC EVOLUTION OF SIGNIFICANT TORNADO DAYS OVER NEBRASKA AND IOWA FROM THE SPRING THROUGH MID SUMMER.

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1. INTRODUCTION

From 1980 through 2005, significant tornadoes, or tornadoes of F2 strength or greater (Fujita 1981), have accounted for only 12 percent of all tornadoes in Nebraska and Iowa but have been responsible for 100 percent of tornado related deaths in that time. Thus for operational forecasters, identification of days when significant tornadoes may occur is very important to fulfilling their mission to save life and property. Figure 1 displays the significant tornadoes in Nebraska and Iowa from 1980 through 2005.

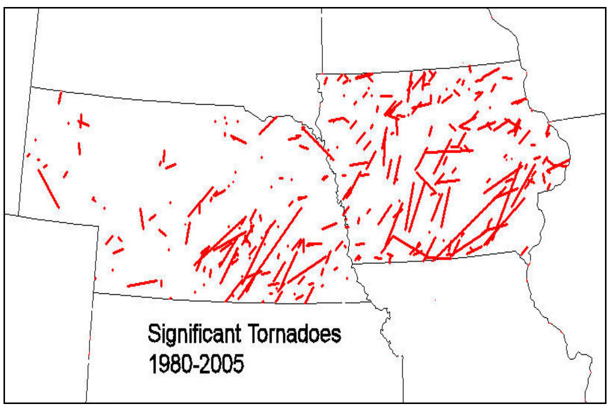

Figure 1. Significant tornadoes in Nebraska and Iowa from 1980 through 2005.

Previous research into the identification of the potential for significant tornadoes has generally taken on two forms. One approach is using an ingredients-based methodology similar to what McNulty (1995) suggested. An ingredients-based method would involve using a checklist of severe weather parameters to assess the potential for a situation to produce significant tornadoes. The second concentration of research centers around varying patterns that would be capable of producing significant tornadoes (Miller 1972).

The goal of this study, using significant tornado days from Nebraska and Iowa from 1980 through 2005 and reanalysis data from NOAA's National Centers for Environmental Prediction (NCEP), was to develop synoptic level composite charts of days on which significant tornadoes occurred. Since the primary convective season for Nebraska and Iowa is from April through July, composites were categorized by month to show the evolution of the typical synoptic situation through the convective season. In addition to the synoptic composites, standard deviations were computed to show areas where the greatest uncertainty exists within these patterns.

2. DATA AND METHODOLOGY

Using the National Oceanic and Atmospheric Administration's (NOAA) National Climate Data Center (NCDC) Storm Data publication, significant tornado days were identified for Nebraska and Iowa from 1980 through 2005. A day was identified as a significant tornado day if one or more tornadoes of F2 strength or greater was reported in either state during a 24 hour period from 1200 UTC through 1200 UTC the following morning. These days were then categorized by month. Table 1 shows the number of significant tornado days for each month included in the study.

Significant Tornadoe Days by Month			
April	May	June	July
17	44	45	19

Table 1. Tornado Days by month.

The composites were developed using NCEP North American Regional Reanalysis (NARR) (Mesinger 2006) data from NCDC. NARR has a 32 km grid resolution and is available at 3 hour increments. The domain area of the study is presented in figure 2. The data were obtained for each significant tornado day at 1800 UTC. Data was then extracted from the model for each tornado day using the General Environmental Meteorological Package (GEMPAK) (DesJardins et al. 1991). The NARR data for each mandatory level in the domain study area was extracted and was then put into a spreadsheet to develop a composite field. The composite field was then imported into a GEMPAK format for display.

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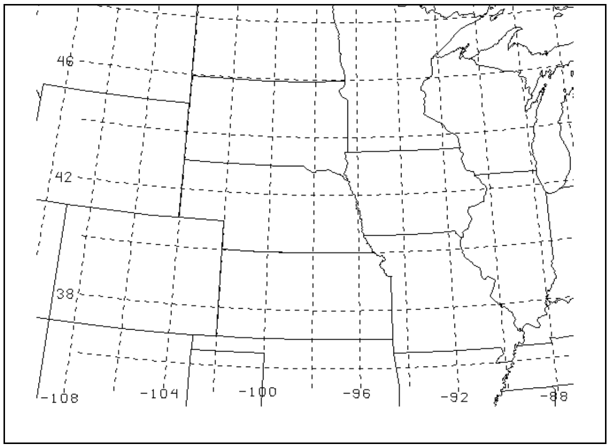

Figure 2. Outline of study area.

3. RESULTS

3.1 Identification and evolution of synoptic features

Figure 3 is the 300 hPa composite for April through July. For the month of April, the composite indicates tornadoes are typically associated with a strong jet from the southwest United States impinging on the Central Plains. There is also a strong signal for a downstream jet of nearly the same magnitude located over the Great Lakes. Strong divergence associated with this coupled jet structure occurs over the majority of Nebraska and Iowa into the Dakotas and Upper Mississippi River Valley leading to enhanced upward vertical motion (not shown). A similar coupled jet signature is also visible in the month of May, although some deamplification of the pattern is noted.

By late spring into early summer, a continued deamplification of the overall pattern is observed, with a general loss of the downstream jet feature over the Great Lakes. Despite the weakening of the jet winds through time, the composite for all months indicates at jet stream segment of at least 20 ms^{-1} is associated with significant tornadoes for Nebraska and Iowa.

Figure 4 is the 500 hPa composite of height and temperatures. Through the spring into early summer, a southwesterly to westerly flow pattern is indicated. For the months of April and May, an identifiable short-wave trough is located within the southwesterly flow. By June and July, the identification of any individual short-wave troughs in the composite is not as clear. In addition, a veering of the 500 hPa height contours is observed from June to July. Cold air advection (CAA) can be inferred in the months of April and May along with a high degree of baroclinicity across the study area with a thermal gradient of 12 to 14 °C. The composite indicates a reduction of this baroclinicity in June and July with a gradient ranging from 6 to 8 °C.

Figure 5 is the composite of height and temperature for 700 hPa. As noted in the previous composites, a general decrease in overall amplification of the pattern is noted through the spring into early summer. Early in the spring, a nearly closed contour is noted in the height field associated with the well defined short-wave trough. Despite the deamplification into early summer, a trough is indicated in the lee of the Rocky Mountains and may be attributed to either a favorable location for a short-wave trough at 1800 UTC or topography.

The evolution of the elevated mixed layer (EML) can also be followed from spring into early summer. Due to the amplification of the pattern in April, the EML appears to spread from the Southern Plains into the Central Plains. By early as May, there is some indication of an EML originating from the Colorado Rockies, though it seems the Southern Plains remains the main source region. As the flow veers at 700 hPa in June and July, the source of the EML appears to be located over the Central Rockies where a +14 °C isotherm is contoured. Also of note, unlike the decrease in baroclinicity through the spring and early summer at 500 hPa, the thermal gradient at 700 hPa remains generally consistent through the period.

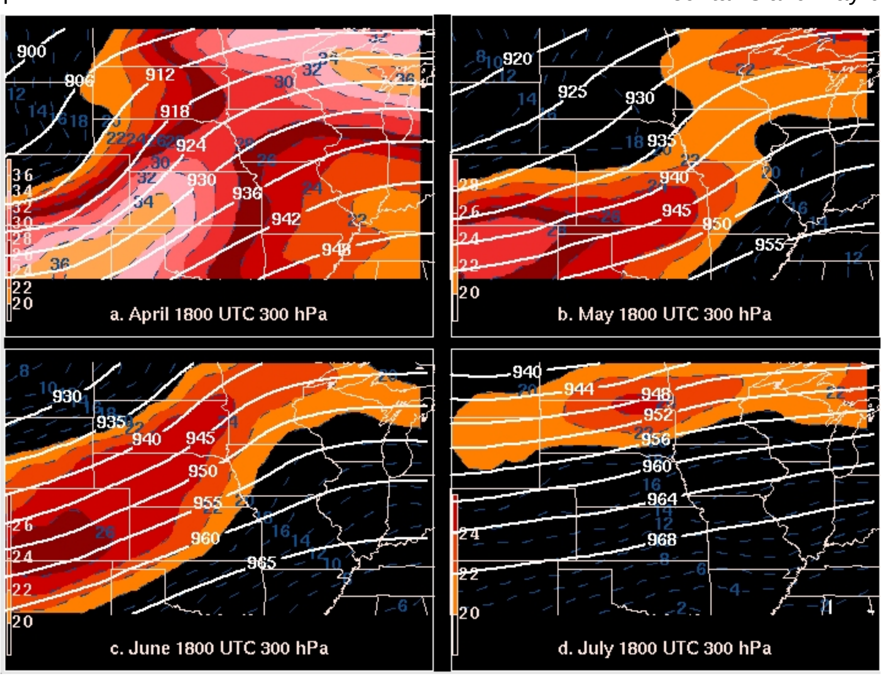

Figure 3. Composite of 300 hPa at 1800 UTC. Solid white contours are heights (dm). Blue dashed lines are isotachs, shaded for values of 20 ms-1 or greater.

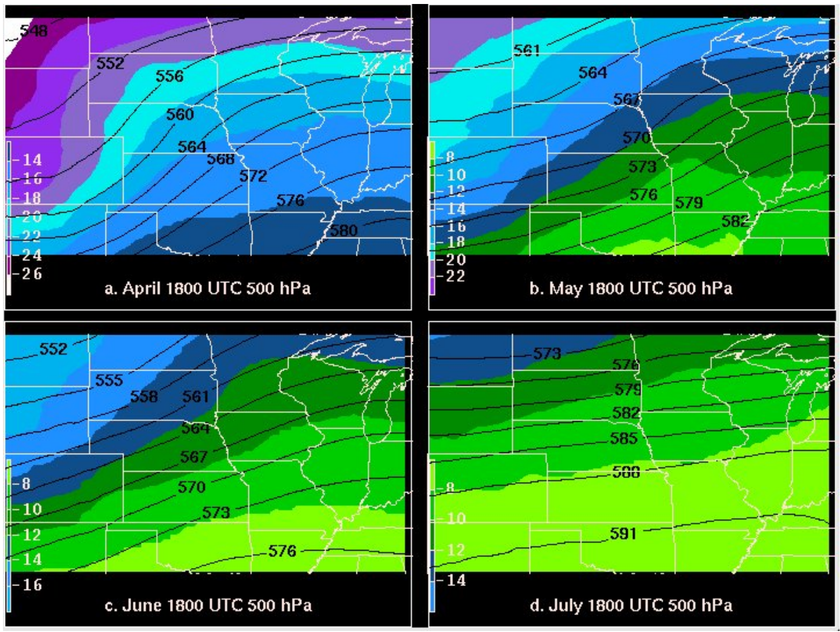

Figure 4. Composite of 500 hPa. Black solid countours are height (dm). Temperatures are shaded ever 2 °C.

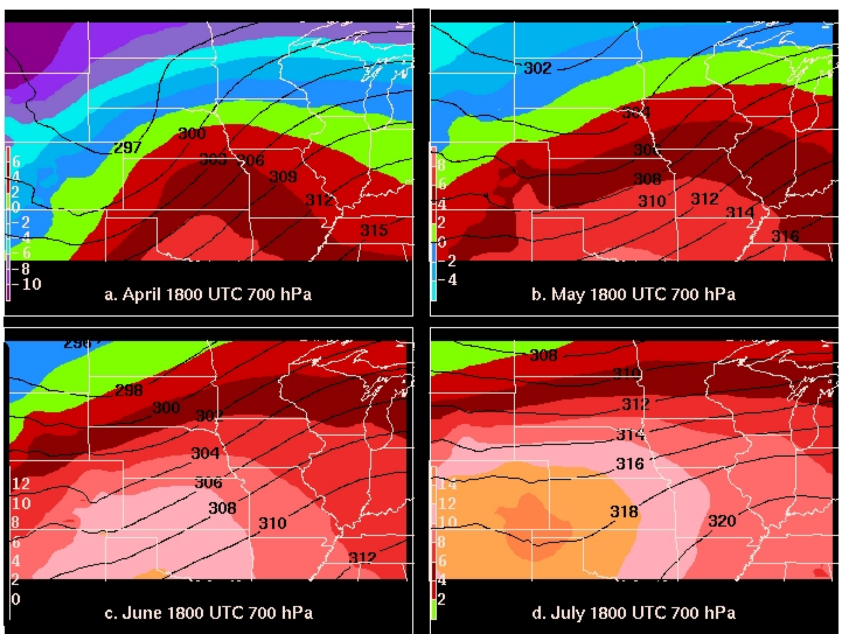

Figure 5. Same as figure 4, but for 700 hPa.

Figure 6 is the 850 hPa composite of height and temperatures. A strong cyclone is indicated in April centered over the High Plains at 1800 UTC. By May, this cyclone is weaker and a little farther north, centered over western Nebraska at 1800 UTC. April and May both show strong support for a warm front from the low pressure into the mid to upper Mississippi River Valley. This also appears to be indicated in the orientation of the thermal gradient from the High Plains into the Great Lakes. As with 700 hPa, the thermal contrast across the study area changes little through the spring into early summer.

The surface composite is presented in figure 7. Consistent through spring into early summer at 1800 UTC is low pressure over the Central Plains. April is characterized by a deep 1000 hPa low located over western Kansas. By May, the low has weakened some but continues to be centered generally over northwestern Kansas. In both of these months, the warm front that was indicated at 850 hPa is also identifiable at the surface. By June and July, although a low is indicated over parts of Nebraska, a well defined warm front is not discernable from the composite.

The composites suggest that with the surface low center located at 1800 UTC generally from Kansas into Nebraska, significant tornadoes in Iowa may occur more in association with the warm front or in the warm sector of the cyclone, and not along a cold front or dryline. By contrast, in Nebraska, closer to the surface low, it appears tornadoes may occur in conjunction with the warm front, dryline, or in the warm sector. It should be noted that mesoscale features are impossible to identify with a composite at this resolution.

3.2 Identification of uncertainty in the patterns

Figure 8 is the standard deviation of the height field at 500 hPa. In areas where the standard deviation is lower, a higher confidence in this particular section of the pattern evolving as the composite would indicate is suggested. Higher standard deviations indicate more uncertainty, and may suggest the pattern has a greater potential to evolve in a different manner than indicated by the composite.

In all the cases, the greatest uncertainty occurs over the Rockies and the Great Lakes. This seems to suggest that although a west to southwest flow is likely across the plains at 500 hPa, the degree of troughing in the western United States and the degree of ridging over the Great Lakes is uncertain. April and May also demonstrate some increased uncertainty in the western

High Plains, likely due to the placement of any migratory short-wave trough. All months also indicate that the

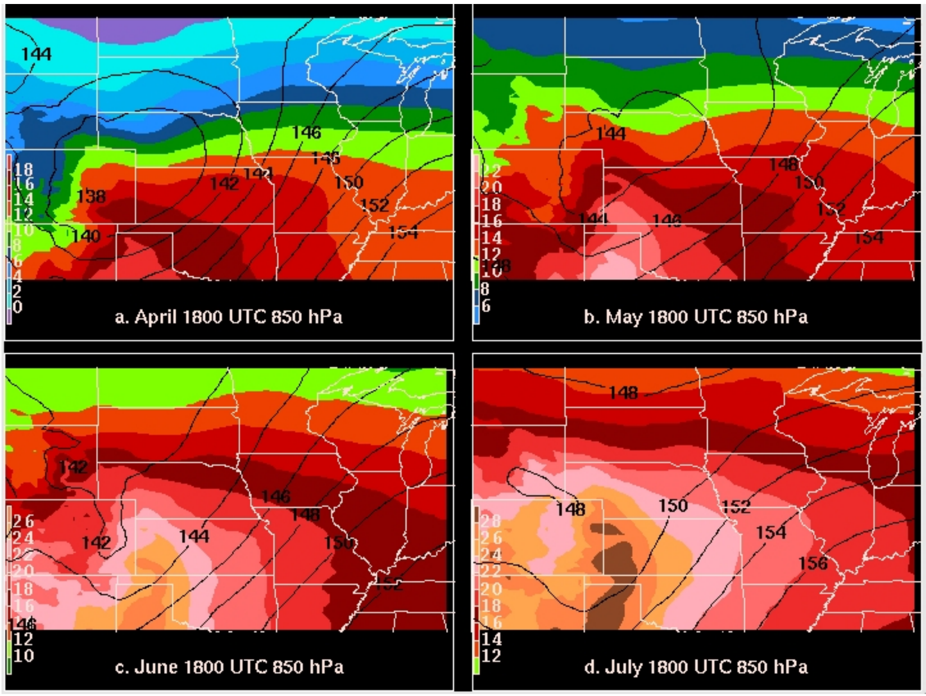

Figure 6. Same as figure 4, but for 850 hPa.

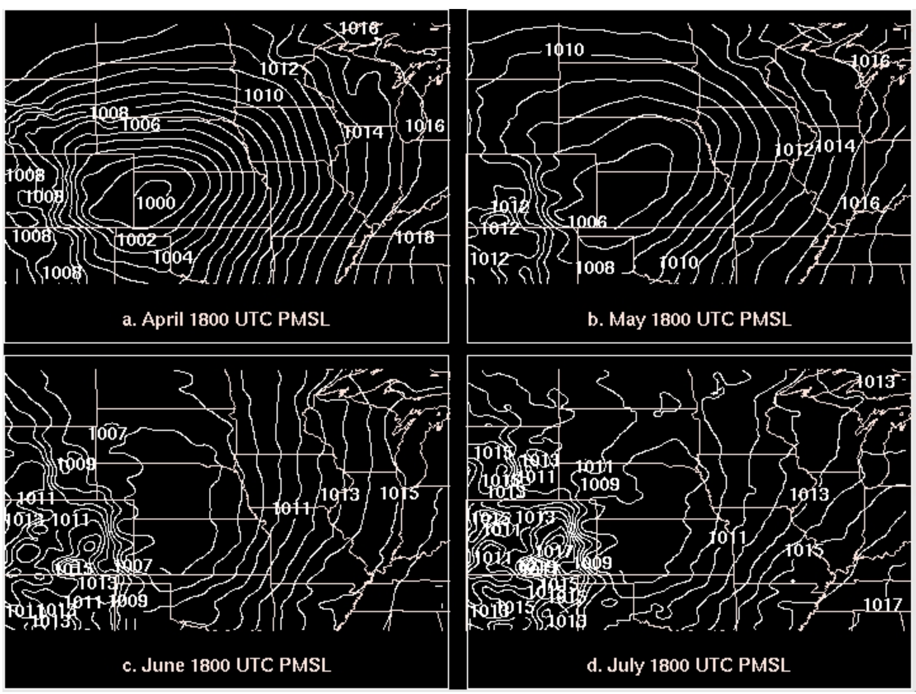

Figure 7. Surface composite at 1800 UTC. Surface pressure controued ever 1 hPa.

lowest uncertainty is from the Southern Plains in the southeastern United States where a ridge is located.

Figure 9 is the standard deviation in the surface pressure composites. At the surface, the most uncertainty exists in the months of May and June. In these two months, the greatest uncertainty exists over the Dakotas into the Great Lakes. This uncertainty may be caused by the variability in the placement of any migratory short-wave trough corresponding to a varied placement on the primary area of high pressure to the north of the surface low. A relatively low uncertainty exists in the month of July likely due to the deamplification of the upper level pattern and weaker short-wave troughs.

4. CONCLUSIONS

Synoptic composites were developed for significant tornado days in Nebraska and Iowa for the months of April through June. The purpose of the composites was to show the general synoptic conditions that produce significant tornadoes during the spring into early summer. In addition, the standard deviation was calculated for the composites to show where the greatest uncertainty in the pattern exists.

The results from the composites indicate westerly to southwesterly mid and upper-level flow across Nebraska and Iowa during episodes of significant tornado development. Although there is a deamplification of the pattern through the spring into early summer with the height fields veering with time, all four months indicate that significant tornado days are associated with a jet max of 20 ms^{-1} or greater. In April and May, there is also a strong signal for a coupled jet structure over Nebraska and Iowa leading to increased large-scale upward vertical motion. The jet maxima are generally associated with a well-defined short-wave trough in the months of April and May, but the jet structure is much

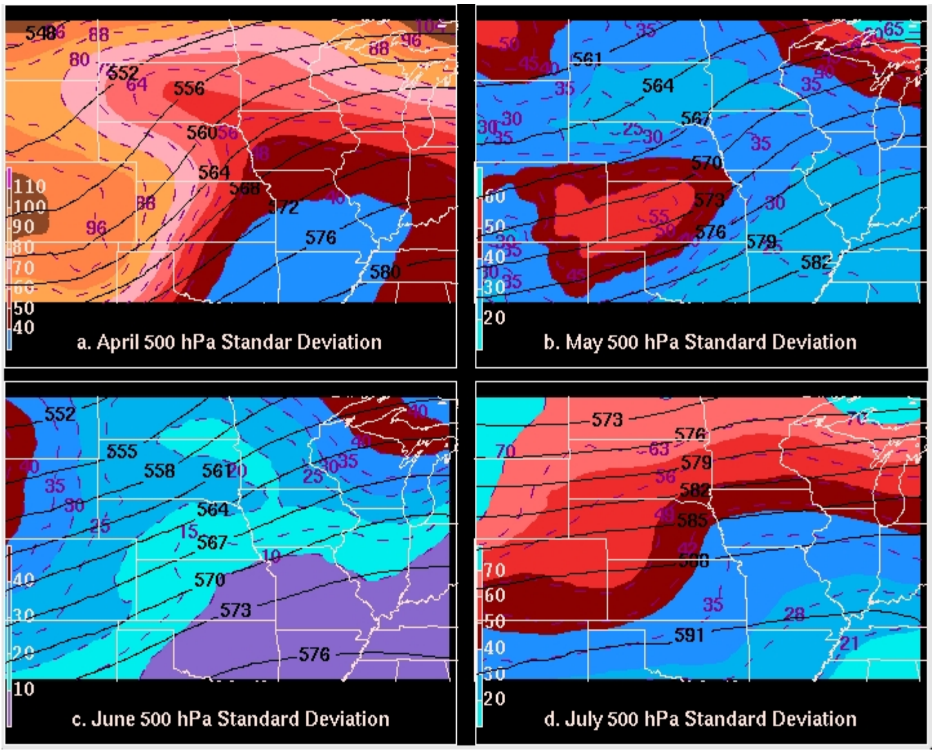

Figure 8. Composite of 1800 UTC 500 hPa including standard deviation. Black countour is 500 hPa heights (dm). Dashed blue lines is standard devation contoured ever 5 dm. Standard devation is shaded ever 10 dm.

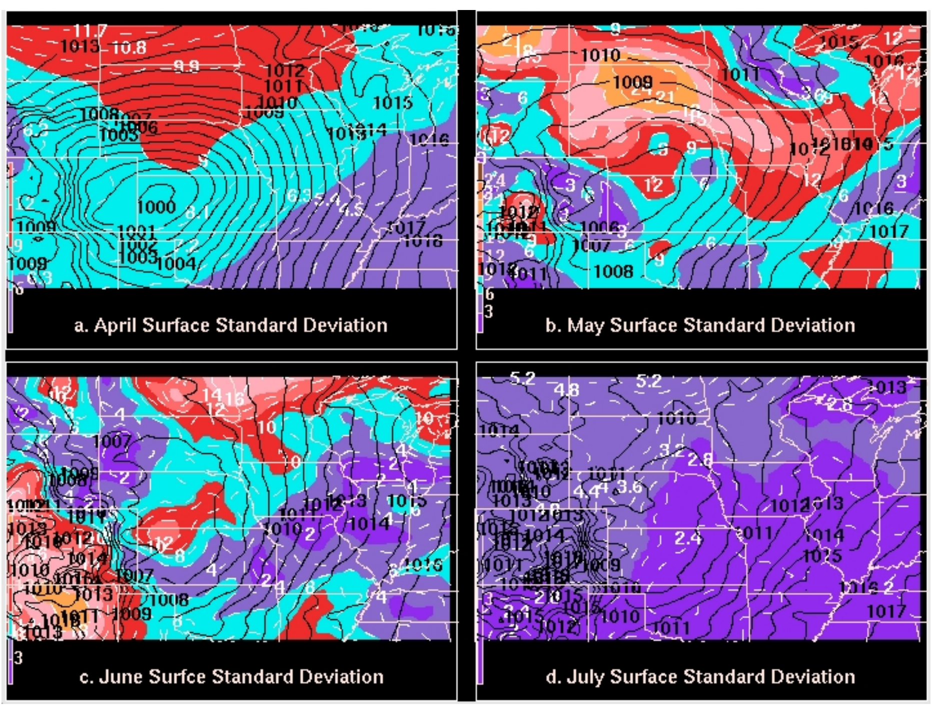

Figure 9. Surface composite at 1800 UTC and stardard deviation. Back contours is surface pressure, contoured ever 1 hPa. Light blue dashed contours is standard deviation. Standard devation is shaded ever 3 hPa.

less defined in June and July. Also of note is the decrease in baroclinicity at 500 hPa from spring into early summer; this was not the case at both 700 and 850 hPa, where this thermal gradient remained generally constant through the period.

The evolution of the EML is apparent at 700 hPa with the source region spreading from the Southern Plains in the spring into the Central Rockies by July. Although short-wave signatures were not easily identifiable at 500 hPa in June and July, the height field at 700 hPa does indicate a weak short-wave trough signature over the western High Plains. On the surface and 850 hPa composites, a strong cyclone is indicated early in the convective season with evidence of a warm front from the High Plains into the Mississippi River Valley. The placement of the cyclone at the surface and 850 hPa suggests that significant tornadoes in Iowa may be more frequently associated with a warm front or in the warm sector of the cyclone. It appears significant tornadoes in Nebraska may occur in several different scenarios, including along the warm front, in associated with the dryline, or in the warm sector of a cyclone.

The standard deviation indicated the most uncertainty in these patterns at 500 hPa resided over the Great Lakes and over the Western United States. The degree of uncertainty in these regions is likely due to the variability of the trough over the Rockies and the amplitude of the ridge over the Great Lakes. The highest confidence was indicated over the southeastern United States where all composites indicated a ridge was located.

The standard deviation at the surface indicated the greatest amount of uncertainty was generally over the Northern Plains into the Great Lakes. There was a higher degree of certainty that a surface cyclone would be located from Kansas into eastern Nebraska with a trough southward into the Southern Plains. The uncertainty across the Northern Plains may be related to the variability in the location of the high pressure indicated over the region, and may imply significant tornadoes can occur in Nebraska and Iowa with or without a surface ridge over the Northern Plains and Great Lakes.

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