P1.5 A SEARCH FOR ENVIRONMENTAL FACTORS IMPORTANT IN THE EVOLUTION OF MORNING GREAT PLAINS MCS ACTIVITY DURING THE WARM SEASON

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1. INTRODUCTION

It is well known that during the warm season, mesoscale convective system (MCS) activity maximizes during nighttime hours over the central United States. Considerable research has been carried out relating to both the initiation and maintenance of this activity during the night, but the dissipation of these systems has received little attention. It is known to forecasters that these systems usually dissipate during the late morning (the four hours or so before local noon). A smaller percentage of the systems continue on into the afternoon, whereupon they may reintensify owing to increased instability in the boundary layer.

The factors that control MCS evolution during this period of the day are not well known; thus, forecasters depend heavily upon trends in system strength from satellite and radar observations, along with their knowledge that in most cases systems dissipate, to make short-term predictions (Hane et al. 2003). The Morning Convection Project, a joint effort among Norman area researchers and personnel at the Norman, Oklahoma and Dodge City, Kansas National Weather Service Offices, was begun a few years ago to better define the scope of this forecast problem and to attempt to identify factors that are important in system evolution.

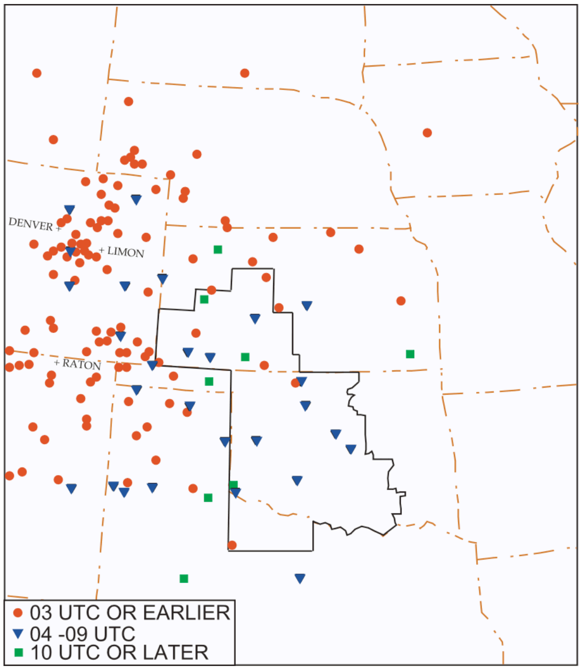

Figure 1. Initiation locations of MCSs included in the climatology Red indicates initiation before 03 UTC; blue, 04-09 UTC; green, after 10 UTC. Black lines enclose county warning areas.

A five-year climatology (1996-2000) that included 145 systems occurring during the warm season (June, July, and August) was carried out by Haynes (2002). To be included, a system had to meet certain criteria involving strength, size, longevity, and speed of motion. The system also had to affect the county warning areas of Norman or Dodge City during the 0900-1700 UTC period of the day. The initiation locations for these systems, as illustrated in Figure 1, are primarily to the west and north of the county

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warning areas. Preferred areas for initiation during the afternoon and evening of the previous day were along ridges that extend eastward from the Rocky Mountains.

An assessment was also made of the evolution of these systems during the late morning (Haynes 2002). It was found that about 60% either decreased in intensity or dissipated during the 1300-1700 UTC period, while another 12% dissipated in the 0900-1300 UTC period. The remaining 28% either remained steady or increased in intensity (only a few cases) during the 1300-1700 UTC period.

2. SYSTEM EVOLUTION IN RELATION TO ENVIRONMENTAL INFLUENCES

It was realized early in the project that examination of the effects of environmental variables on MCS evolution through use of observed data would involve great challenge, principally owing to the lack of both temporal and spatial resolution in such data. The decision was made to use Rapid Update Cycle (RUC-2) analysis gridded data to characterize the environment of these systems. Unfortunately, there were inconsistencies in the analysis archive prior to the summer of 1999, so that only the last two years of the MCS climatology could be included. Additionally, of the 63 MCSs included in the climatology during the summers of 1999 and 2000, only 48 had sufficiently complete corresponding RUC-2 data for an assessment to be made.

To characterize the environment of individual systems, hourly soundings were extracted from the RUC-2 analyses 50 km ahead (along the system track) of each observed system (i.e., the location of soundings moved with the system). Spot checks were carried out at locations 100 km ahead, and no significant differences in environmental profiles were found. RUC-2 sounding profiles were also compared with observed data from rawinsonde ascents at 1200 UTC at Norman and other locations. The only inconsistencies found were in the low-level wind speeds. The RUC-2 analysis soundings, when the low-level jet was present, consistently underestimated the speed of the jet and placed it at a greater altitude than observed. Therefore, in certain cases, such quantities as the low-level wind shear based on the RUC-2 analysis are in error.

The set of 48 cases was divided into two classes based on MCS evolution in the 1300-1700 UTC period. Those that were decreasing or dissipating were placed in the ‘”decreasing“ category (32 cases), and those that were steady or increasing in the “non-decreasing” category (16 cases). Various environmental quantities were then calculated at each hour in the 0900-1900 UTC interval, based upon the RUC-2 analysis soundings. At 1500 UTC composite soundings were produced for the two categories by averaging the profiles of individual members. An example of a composite hodograph pairing is shown in Figure 2. Two potentially significant features stand out. The cloud layer shear vector and system motion direction are nearly coincident in each class, and are oriented in significantly different directions between the two classes. Secondly, in the non-decreasing class, there is a tendency for the shear within an elevated layer (600-350 hPa) to deviate to the left of the system motion direction. This shear layer difference between the two classes implies differences in thermal advection aloft that may affect stability, or it may indicate a potential difference in microphysical processes between the two classes.

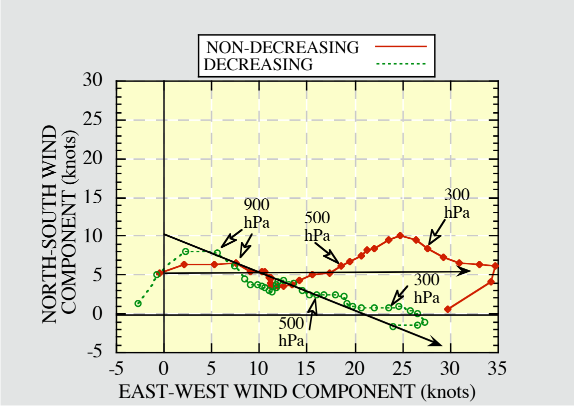

Figure 2. Composite hodographs for the two classes of system evolution. Black arrows denote mean system motion direction for each class. Pressure levels are noted at several points along each curve.

A large number of environmental variables were calculated for the purpose of comparison with the character of MCS evolution. These variables included convective available potential energy (CAPE), lifted index, vertical wind shear in the plane of system motion over a variety of surface-based and elevated layers, horizontal flux of mass and water vapor toward the system over a variety of surface-based layers, north-south wind component at 350 hPa, "shear offset" (to be defined), and low-level geostrophic thermal advection. In addition, the speed and direction of system motion were examined in relation to system evolution character. The inclusion of 350 hPa wind component and "shear offset" was a response to the differences in composite wind profiles between the two classes of evolution illustrated in Fig. 2. "Shear offset" is the difference between the 600-350 hPa shear vector and the system motion direction measured along a line normal to the system motion. Positive values of this quantity represent deviation of the shear direction over this layer to the left of the system motion direction.

These variables have so far been examined in pairs in relation to the character of system evolution by the construction of scatter diagrams. The values of variables were taken from the RUC-2 analysis soundings at 1500 UTC (midway in the period in which the character of system evolution was assessed). Changes in individual values of the same set of parameters over the 1300-1700 UTC period were also calculated and paired both with parameter values at 1500 UTC and with changes in other parameters in the list. A few examples of the results based upon these scatter diagrams are shown here.

The first example (shown in Figure 3) involves the pairing of CAPE and 0-10 km shear. It is expected that higher values of CAPE and larger shear values would be associated with higher probability of system maintenance. This is indeed the case, as indicated by the clustering of "decreasing" class systems in the low CAPE-low shear portion of the diagram. If the diagram is divided into two CAPE/shear regimes (line in figure), percentages of each class of evolution in each regime might be calculated. It should be noted that the division into regimes (placement of line) is somewhat arbitrary, and different percentages would result from different placements. In this example, in the lower left regime 95% of the cases fall in the decreasing class, while in the upper right 58% fall in the non-decreasing class. Use of such a diagram is potentially useful to forecasters in the 95% regime, since the climatology has indicated that about 67% of all occurrences fall in the decreasing class. If a case falls in the 58% regime, there is no improvement upon the result of the climatology. In this case there are 22 systems in the 95% regime, so that such a diagram would be useful less than half the time. The same diagram constructed using 0-2 km shear in place of the deep level shear yields similar results, but the general impression from combination of shear with other variables is that the deep level shear is a slightly better predictor of evolution.

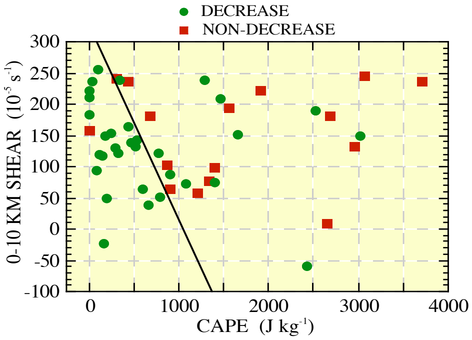

Figure 3. Scatter diagram of two classes of evolution plotted as a function of CAPE (J kg^{-1}) and 0-10 km vertical wind shear (10^{-5} s^{-1}).

The water vapor flux into the MCS (inward flux a negative number) in the plane of system motion was evaluated in layers above the surface both 2 km and 4 km deep. A scatter plot of 0-2 km flux versus lifted index is shown in Figure 4. As expected, more negative lifted index and more negative water vapor flux associate with high probability of system maintenance. In this example, 95% of the systems in the upper right regime (20 MCSs) are in the decreasing class, while only 54% in the lower left regime (28 MCSs) are in the non-decreasing class. Thus, such a diagram is potentially useful only over part of the two-parameter area. Similar percentages are realized if CAPE or lifted index is paired with the north-south wind component at 350 hPa, where "decreasing" systems associate strongly with lower stability and relatively less positive

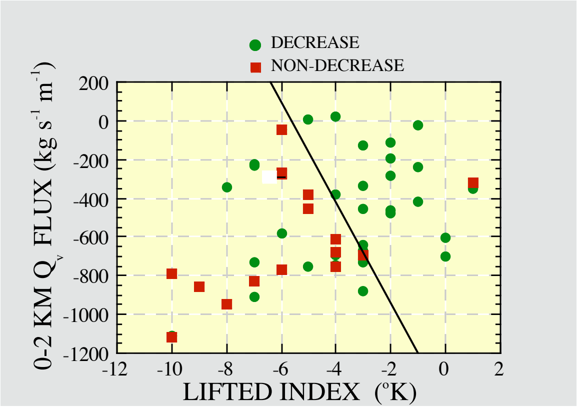

Figure 4. As in Figure 3, but plotted as a function of lifted index (°C) and water vapor flux (kg s^{-1} m^{-1}) into the system.

values of the wind component (not shown).

As was noted above, positive values of "shear offset" were associated with the non-decreasing class of systems when the composite hodographs were constructed. Pairing of stability parameters with shear offset produced the most discriminating result (with respect to evolutionary character). This is shown in Figure 5, where cases are plotted as a function of CAPE and shear offset. In the upper right regime (high CAPE and relatively large shear offset), 75% of the 16 cases are in the non-decreasing class, while in the other regime 88% (of 32 total cases) are in the decreasing class. This is an encouraging result, as percentages are higher than predicted by "climatology" over the entire space. A larger sample would naturally increase confidence in this and other results, and operational testing would also be necessary.

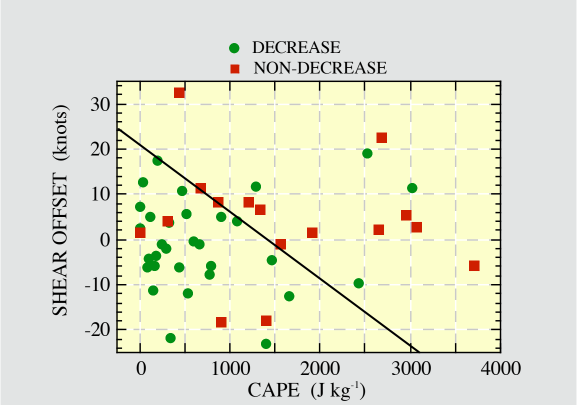

Figure 5. As in Fig. 3, but the ordinate is shear offset (knots).

In interpretation of the composite hodographs in Figure 2, it was noted that there is a potential difference in system motion direction between the two classes of evolution. Direction of system motion was therefore paired with a series of variables. Shown in Figure 6 is the scatter diagram resulting from the pairing of system direction with CAPE. The tendency of the decreasing class of systems to associate with lower CAPE values and motion more from the west-northwesterly to northwesterly directions can be seen. In the lower right regime, which contains only 8 cases, all are in the non-decreasing class. At upper left the regime contains 40 cases, and 80% of these are in the decreasing class. The small sample in the lower right regime is a concern, but this result could perhaps be combined with others to help discriminate between classes of evolution.

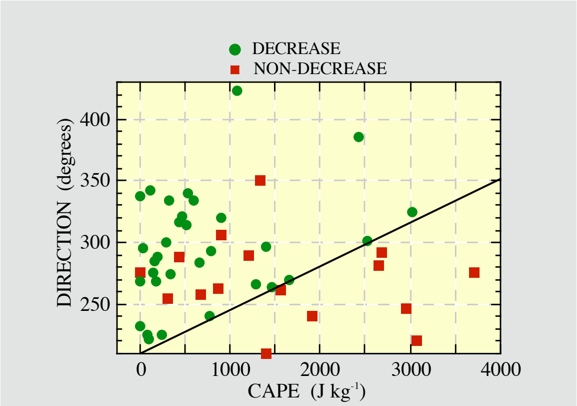

Figure 6. As in Fig. 3, but ordinate is system direction. Directions beyond 360° are included to facilitate plotting.

System speed was similarly paired with a series of other variables. A number of pairings resulted in percentages that marginally exceeded "climatology" over the entire parameter range (not shown). The decreasing class tended to associate with lower values of system speed. Since the development of widespread deep convection has been linked to upward motion resulting from large-scale low-level thermal advection (Maddox and Doswell 1982), an attempt was made to evaluate low-level thermal advection for this set of MCSs to determine if there is also a link with the maintenance of existing systems. As a preliminary step, an estimate of geostrophic thermal advection was evaluated from individual soundings by calculating the degree of veering or backing of the wind profile over the lowest 200 hPa above the surface. Somewhat surprisingly, there tended to be a large percentage of systems in the non-decreasing class that were associated with negative or relatively small positive values of geostrophic warm advection. In the near future, the low-level thermal advection will be evaluated more directly from the RUC-2 analyses to determine whether a different result arises.

Changes in all the parameters mentioned (except storm motion parameters) were also evaluated and paired to produce scatter diagrams. This involved a total of 108 parameter pairs. In almost all cases, this evaluation resulted in physically plausible relationships (e.g., a positive time change in CAPE was associated more with MCS maintenance than MCS dissipation). In general, pairings involving changes in parameters showed promise at a level comparable to single-time parameters. A potential concern lies in the calculation of these changes in an operational setting where changes in forecast values over a few hours would be employed.

3. FUTURE WORK

Work within this project to date has employed rather simple methods to evaluate results. It is planned to investigate the possibility of using other methods to evaluate relationships between environmental variables and the character of morning MCS evolution. A natural extension of what has been done would be to apply three-dimensional visualization software to the calculated parameters, allowing the evaluation of the effects of triplets of some of the more promising variables. Another possibility is the application of discriminant analysis. Larger sample size is desirable for increasing confidence in results, so that collection of cases during the summers beyond the year 2000 will be pursued.

The ultimate goal of this project is to provide a tool for operational forecasters that will help provide more accurate short-term forecasts. Therefore, once results are further refined, testing in an operational setting of tools produced by this project will be an important step.

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