P3M.6 ON THE IMPORTANCE OF ENVIRONMENTAL FACTORS IN INFLUENCING THE EVOLUTION OF MORNING GREAT PLAINS MCS ACTIVITY DURING THE WARM SEASON

Carl E. Hane
NOAA/National Severe Storms Laboratory, Norman Oklahoma

David L. Andra, Jr.
NOAA/National Weather Service Forecast Office, Norman, Oklahoma

John A Haynes[1], Therese E. Thompson, and Frederick H. Carr
School of Meteorology, University of Oklahoma, Norman, Oklahoma

1. INTRODUCTION

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. 2003a). 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.

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 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. The climatological study has been extended to include the 2001-2004 period (2005 will be added soon). The same criteria for inclusion were used for this later period. An additional 136 cases were added to the climatological study during these years. Figure 2 shows the geographical distribution of initiation locations for the 1996-2004

---

[1]*Present affiliation:* National Aeronautics and Space Administration, Washington, DC.

Corresponding Author Address: C.E. Hane, NOAA/NSSL, 1313 Halley Cir., Norman, OK 73069

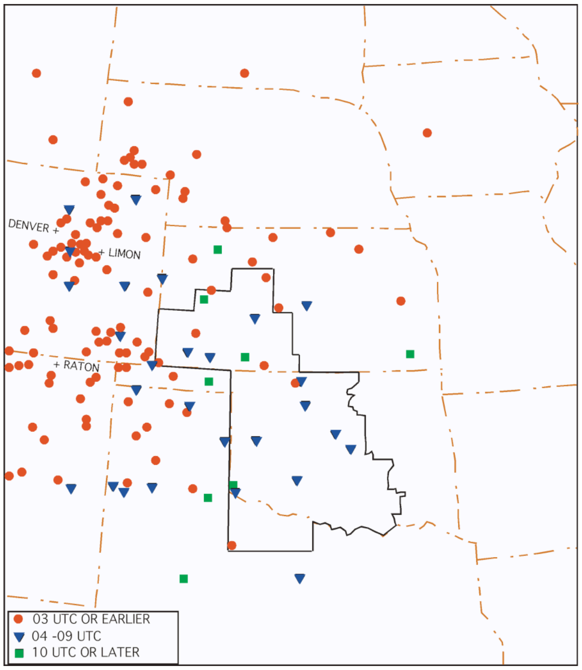

Figure 1. Initiation locations of MCSs included in the climatology Red indicates initiation before 03 UTC; blue, 04-09 UTC; green, after 10 UTC. Black lines enclose county warning areas.

period (281 cases). It can be seen that a large fraction of the systems were initiated on the previous day. The tendency for initiation to occur along ridges extending eastward from the Rocky Mountains (the Raton Mesa, the Palmer Divide, and the Cheyenne Ridge) is evident (as in the 1996-2000 period alone). There appears to be a greater tendency for initiations northeast of Denver (likely related to the presence of the Denver Convergence Zone) in the later period. The absence of initiation locations in the Arkansas River Valley of eastern Colorado is striking. An assessment was also made of the evolution of these systems in the 1996-2000 period 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

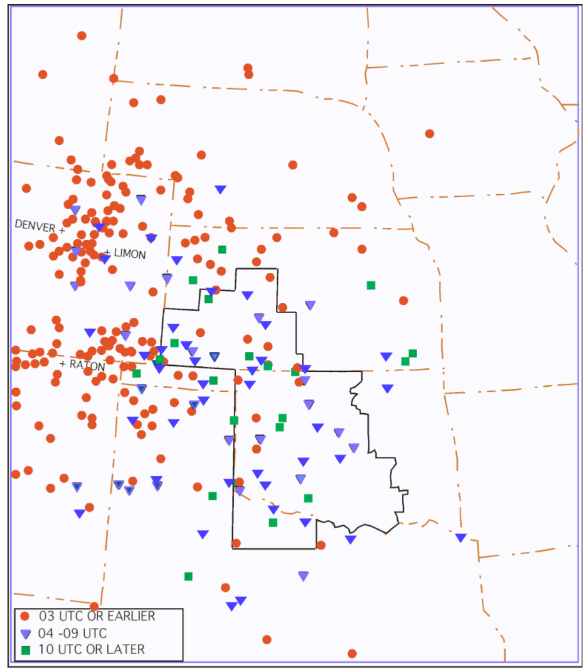

Figure 2. Initiation locations for all cases in the 1996-2004 period. Initiation time periods are indicated as in Fig. 1.

intensity (only a few cases) during the 1300-1700 UTC period.

2. SEVERE WEATHER OCCURRENCES

Severe weather occurrences with the 136 MCSs that occurred in the 2001-2004 period were investigated based upon archived information from the NOAA/Storm Prediction Center. It was found that 87 of the 136 cases (64%) had some form of severe weather during their existence. A total of 2274 reports were logged with these systems. Hail reports were most numerous with 53% and damaging wind next with 46%. Tornado occurrences were infrequent during this period of the day. By month, June had the most severe weather reports, followed by August, with relatively few reports in July. A similar accounting during the 1996-2000 period showed that wind damage reports outnumbered hail reports by almost two to one.

3. SYSTEM EVOLUTION IN RELATION TO ENVIRONMENTAL INFLUENCES

Another major part of the project has been to identify environmental factors that are important in influencing the evolution of these systems (Haynes 2002; Hane et al. 2003b). The decision was made to use Rapid Update Cycle (RUC-2) analysis gridded data to characterize the environment of these systems rather than observed data, owing to the lack of temporal and spatial resolution in observed data. Unfortunately, there were inconsistencies in the analysis archive prior to the summer of 1999, so that only the last two years of the 1996-2000 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. Efforts are now underway to add the 2001-2005 cases to the environmental influence investigation.

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) to characterize the environment of individual systems. 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 a low-level wind maximum was present, consistently underestimated the speed of the wind maximum and placed it at a greater altitude than observed. Therefore, in certain cases, such quantities as the low-level wind shear and the flux of water vapor into the system based on the RUC-2 analysis are in error. These wind speed discrepancies will be documented in a future paper.

The set of 48 cases from 1999-2000 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 3. Two potentially significant features stand out. The cloud layer shear

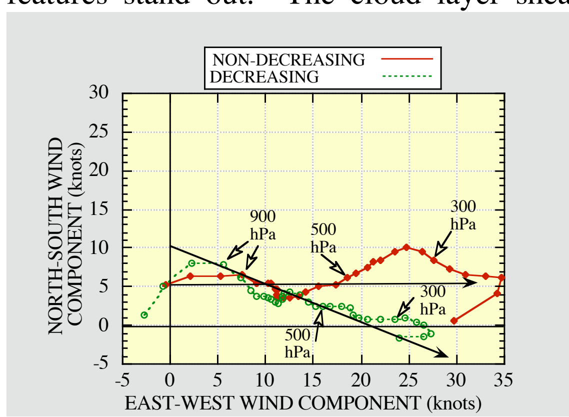

Figure 3. Composite hodographs for the two classes of system evolution. Black arrows denote mean system motion direction for each class. Pressure levels are noted at several points along each curve.

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.

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, and "shear offset" (to be defined). 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. 3. "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 were first 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 4) 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

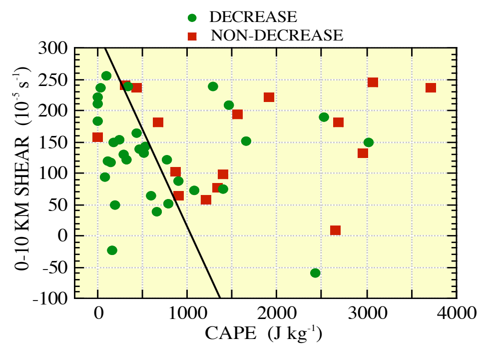

Figure 4. Scatter diagram of two classes of evolution plotted as a function of CAPE (J kg^{-1}) and 0-10 km vertical wind shear (10^{-5} s^{-1}).

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.

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

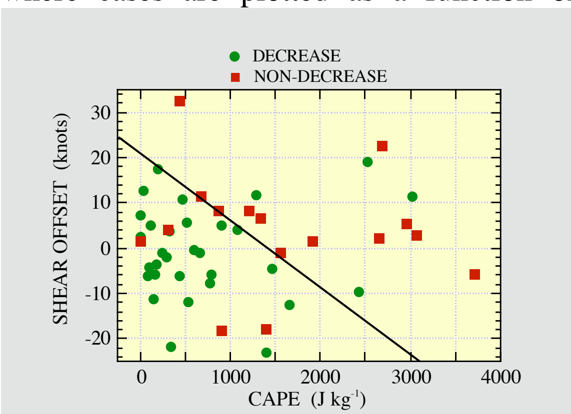

Figure 5. As in Fig. 3, but the ordinate is shear offset (knots).

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.

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.

Recent work has employed discriminant analysis in an attempt to identify combinations of environmental factors that have strong influence on determination of system evolution between the two categories mentioned previously. One advantage of this approach is that it produces a more objective determination of the division between regimes. To date a total of 61 combinations have been evaluated using this approach. The table below shows results from some of the more promising combinations.

The first column in the table (COMBO) includes 3-variable combinations including convective available potential energy (ca), direction of system motion (dir), shear offset (sof), system speed (spd), 0-2 km water vapor flux toward system (qf2), 350 hPa north-south wind component (v35), lifted index (li), 0-2 km shear in the plane of system motion (s02), and 0-4 km water vapor flux (qf4). The second column (G1) includes the number and percentage of correct classifications within the "non-decreasing" evolution regime. The third column (G2) lists the same quantities within

COMBO	G1 (steady)	G2 (decrease)	CC
ca/dir/sof	12/16 75.0%	28/32 87.5%	40
ca/spd/sof	12/16 75%	28/32 87.5%	40
ca/qf2/v35	13/19 68.4%	26/29 89.7%	39
li/s02/spd	10/13 76.9%	29/35 82.9%	39
li/qf4/dir	11/15 73.3%	28/33 84.8%	39
li/sof/dir	12/15 80.0%	29/33 87.9%	41

the "decreasing" evolution regime, and the last column (CC) lists the total number of correct classifications (out of 48 possible).

4. FUTURE WORK

Cases from the 2001-2005 period will be added to both the climatological and environmental influence portions of this project. The additional cases will be especially valuable in identifying environmental influences, as it will significantly increase the sample size and include a time period when RUC low-level wind analyses are more accurate. The ultimate goal of this project is to provide a tool for operational forecasters that will help provide more accurate short-term forecasts. Once results are further refined, testing of tools produced by this project will be undertaken in an operational setting.

ACKNOWLEDGEMENTS

The authors are grateful to S. Fletcher, D. Kennedy, B. Schmidt, and R. Coggins for computer support and to P. Bothwell and J. Hart for facilitating data acquisition. A portion of the support for this work has been and is being provided by COMET through two NWS cooperative project grants.

REFERENCES

Hane, C.E., J. D. Watts, D. L. Andra, J. A. Haynes, E. Berry, R. M. Rabin, and F. H. Carr, 2003a: The evolution of morning convective systems over the U. S. Great Plains during the warm season. Part I: The forecast problem. *Wea. Forecasting*, **18,** 1286-1294.

Hane, C. E., J. A. Haynes, and D. L. Andra, Jr., 2003b: A search for environmental factors important in the evolution of morning Great Plains MCS activity during the warm season. 10th Conf. on Mesoscale Processes, Amer. Meteor. Soc., CD.

Haynes, J.A., 2002: Analysis of warm season morning convection across the southern Great Plains. M. S. Thesis, University of Oklahoma, 119 pp.