11A.2 Forecasting Short Term Convective Mode And Evolution For Severe Storms Initiated Along Synoptic Boundaries

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1. Introduction

Forecasting convective mode (discrete cells versus lines) and evolution continue to represent unique forecasting challenges. A more skillful forecast of severe weather would likely result from a correct anticipation of convective organization and evolution. Historically, buoyancy and vertical shear have been shown to be discriminators for supercell versus non-supercell modes (e.g. Weisman and Klemp 1982,1984). Other parameters, however, appear to play a substantial role in determining how thunderstorms will evolve once initiated, and attempts at focused research to address this problem have been limited. Bluestein and Jain (1985) and Bluestein et al (1987) investigated parameters believed to influence the nature and evolution of spring squall lines in Oklahoma. Bluestein and Parker (1993) investigated modes of severe storms initiated along the dryline. Also, Parker and Johnson (2000) studied modes of MCS's. Modeling studies include work done by Bluestein and Weisman (2000) and Weisman et al (1988). The primary objective of this research is to investigate environmental parameters that may exhibit skill in discriminating between situations where thunderstorms evolve into lines and those where storms remain discrete during the few hours after initiating along boundaries such as cold fronts, dry lines and pre-frontal convergence zones.

2. Data and Methodology

The data included in this study are associated with severe weather events east of the Rocky Mountains during the fall of 2003 through the summer of 2004. Most of the cases collected so far include events east of the Rocky Mountains but along and west of the Mississippi river valley. The data base includes cases where: 1) surface-based thunderstorms initiated along a synoptic boundary, 2) the storms produced one or more reports of large hail, damaging wind, and or tornadoes, and 3) the 0-6 km AGL vertical shear was 30 kt or greater. Data used to populate the database was collected from observed or RUC model proximity soundings (Thompson et al,2003), radar, satellite, surface observations, and objective analyses based on a combination of RUC and observed data (Bothwell et al 2002). The type of boundary was also documented.

About 80% of the data used in this study was obtained from RUC model proximity soundings and about 20% from observed soundings. Our definition of proximity includes soundings within 75 km and 1 hour of the time the first few storms develop. In an attempt to isolate those parameters that may show skill in discriminating between situations where storms evolve into lines versus those where storms remain discrete within 3 hours of being initiated along a synoptic boundary, several kinematic and thermodynamic parameters were investigated. Kinematic parameters investigated include the wind convergence along the boundary averaged through the lowest 90 mb, the 0-2 km and 0-6 km shear, the 2-6 km or 2-8 km shear normal to the initiating boundary and 2-6 km or 2-8 km mean wind, as well as the angle between the mean wind and the boundary. The layers used in the shear and mean wind calculations (2-6 km or 2-8 km) depended on the depth of the convective cloud. The 2-6 km layer was used when estimated maximum storm tops were at or below 9 km above ground level (AGL), and the 2-8 km layer was used when estimated maximum storm tops were above 9 km AGL. Wind convergence was obtained from a GEMPAK objective analysis script that calculates the convergence incorporating hourly RUC and observed surface data. Several thermodynamic variables including mean mixed CAPE, convective inhibition (CINH), lifted condensation level (LCL) height, level of free convection (LFC) height, as well as surface-850 mb, and 850 mb-700 mb layer averaged relative humidity were also collected. However, based on the current database, these parameters appeared to show little skill in discriminating between discrete and linear evolutions. If environmental parameters such as shear, CAPE, boundary orientation etc. varied significantly along the boundary, then the boundary was divided into more than one segment. All data collected were imported into spreadsheets where initial statistical results have been calculated.

It must be emphasized that only those storms observed to be initiated along a linear boundary were investigated in this study. Evolution of storms that may have initiated in the warm sector away from a synoptic boundary were not considered, but may be investigated as a separate research project in the future.

Data from 37 cases are examined including 16 events in which the storms remained discrete within the first 3-4 hours, 7 events where mixed modes (defined as cases where both discrete cells and line segments were both present after 3 hours) were observed, and 14 events where storms evolved into lines. Figures 1-3 show examples of what were classified as linear mode, a mixed mode and a discrete mode at roughly 3-4 hours after the storms initiated. We classified storms as lines when the 35 dbz or greater reflectivity pattern showed a length to width ratio of at least 5 to 1. Storms were classified as discrete when the maximum reflectivity between identifiable cells did not exceed 25 dbz.

3. Discussion And Preliminary Results

From a conceptual standpoint, the ability of storms to evolve into lines would appear to depend in part on (1) the number of storms initiated, (2) the ability of storms and their associated convective outflows to interact and organize a cold pool, and (3) the ability to continually initiate new updrafts along the leading edge of the cold pool. The number of storms initiated would appear to be a function of the amount of convective inhibition and the magnitude and nature of linear forcing in the lowest few kilometers. The ability of storms to interact and organize a cold pool depends partly on the number of storms initiated, storm motions, the distribution of precipitation, as well as thermodynamic parameters that enhance evaporative cooling. The distribution of precipitation depends partly on the magnitude and orientation of cloud layer vertical shear and mean flow with respect to the initiating boundary.

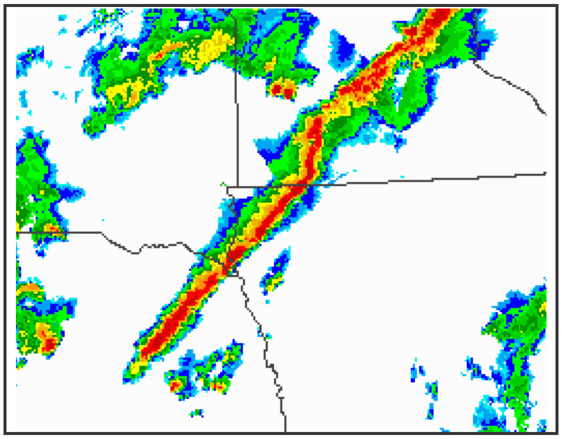

Figure 1. Linear Mode Example

Only some of the variables mentioned above will be investigated in this study. In our database, parameters that show the most skill in discriminating between discrete and linear evolutions are the lowest 90 mb mean wind convergence (a measure of initiation potential), orientation of the 2-6 km or 2-8 km mean wind with respect to the initiating boundary, and magnitude of the 2-6 km or 2-8 km shear normal to the boundary (kinematic parameters that influence the distribution of precipitation and potential for storms to develop a cold pool upstream from the updrafts).

Figures 4-6 are box and whiskers plots of the parameters that showed the most sensitivity to mode evolution. Fig. 4 is a box and whiskers plot of the orientation of the mean flow in the 2-6 or 2-8 km layer with respect to the initiating boundary. No overlap exists between the 75th percentile rank for the line cases and the 25th percentile rank for the discrete cell cases, suggesting this parameter has good skill in discriminating between those situations where storms evolved into lines and those where storms remained discrete within the first 3 hours after initiation. This parameter suggests that when the mean mid-upper level flow is nearly parallel to the initiating boundary, a faster evolution into lines is more likely. There was also a tendency for storms that remained discrete longer than 3 hours to develop along boundaries with weaker low level convergence (Fig. 5). Assuming thermodynamic parameters such as CINH and LFC height are similar along the initiating boundary, stronger low level convergence would in general promote the development of more storms which would in turn increase the chances for storm mergers and lines. Fig. 6 suggests there is a strong preference for storms that remain discrete for 3 or

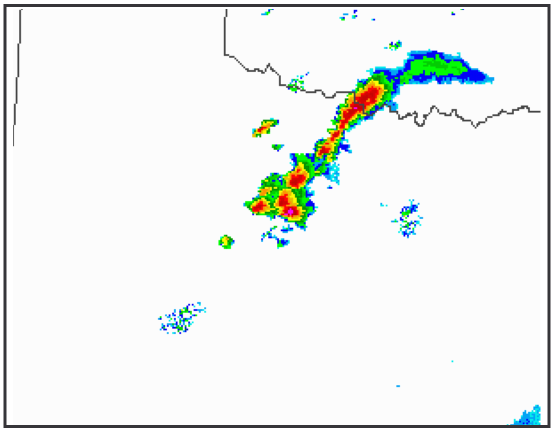

Figure 2. Mixed mode example containing both a line segment and cells

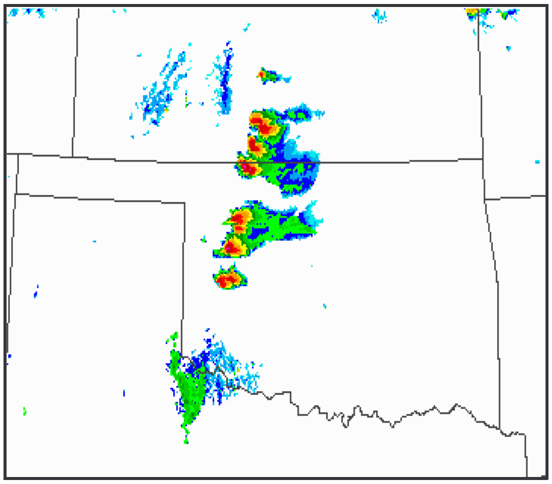

Figure 3. Discrete mode example.

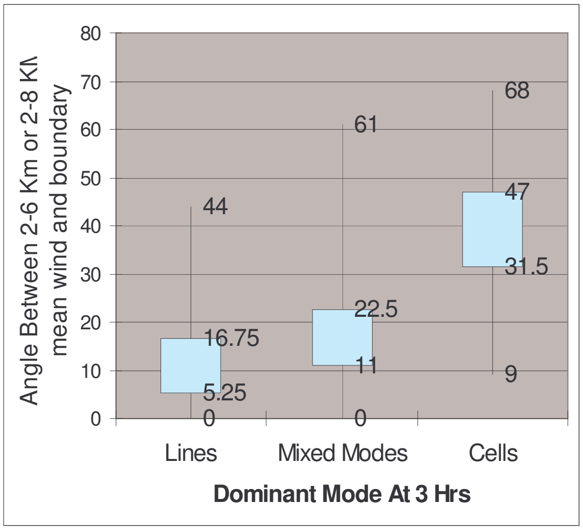

Figure 4. Box and Whisker Chart of the angle in degrees between the 2-6 km or 2-8 km mean wind and boundary. The top and bottom of the shaded boxes represent the 75th and 25th percentiles, respectively. The vertical lines extend upward to the maximum and downward to the minimum values.

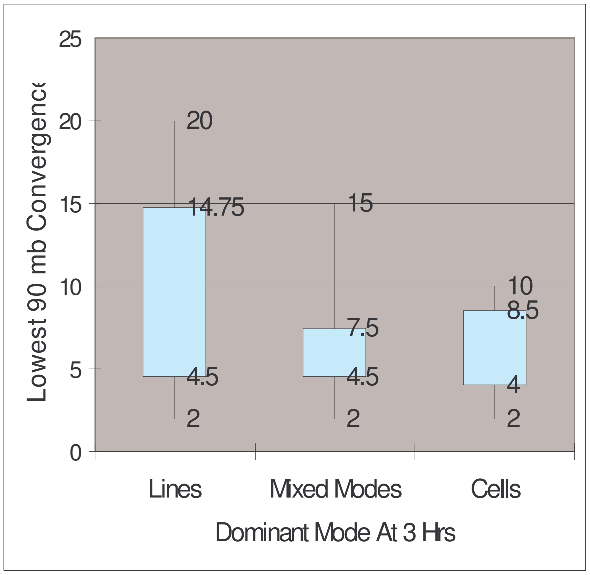

Figure 5. Same as fig. 4 except for low level convergence X $10^{-5}s^{-1}$.

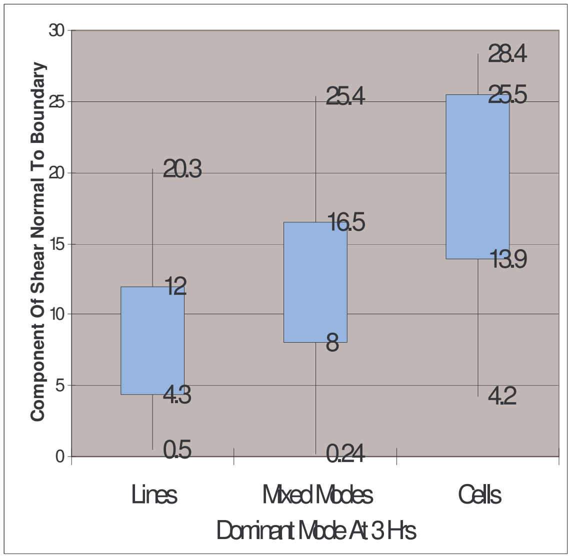

Figure 6. Same as fig. 4 except for normal component of shear in ms^{-1}.

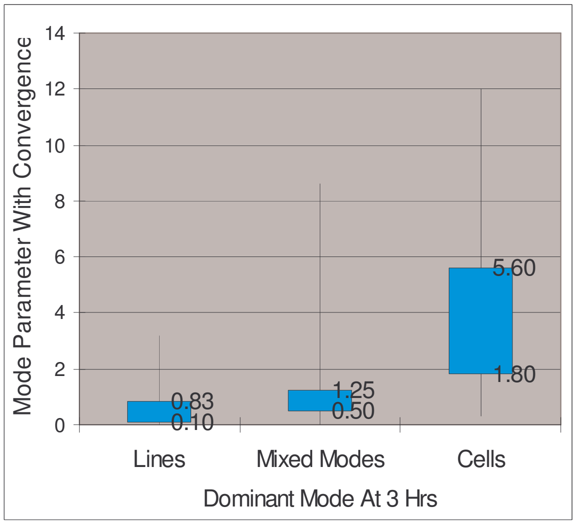

Figure 7. Same as fig. 4 except for mode parameter.

more hours to develop in environments where the component of shear normal to the initiating boundary in the 2-6 km or 2-8 km layer is stronger. This is consistent with theoretical concepts and model simulation work done by Weisman et al (1988) in which stronger shear through the middle levels normal to the line of forcing promoted an evolution where storms remained more discrete in character. A normalized mode parameter was developed based on these 3 individual parameters. The parameter was formulated such that it would show lower values when evolution into lines within 3 hours of initiation are favored and higher values when persistent discrete modes are favored. The normalized mode parameter used in this study is defined to be:

$$M = \left(\frac{A/25 \times S/13}{C/9} \right)$$

where A is the angle in degrees between the initiating boundary and the mean wind in the 2-6 km or 2-8 km layer (normalized with respect to 25 degrees) and S is the component of the shear in m/s within the 2-6 km or 2-8 km layer orthogonal to the initiating boundary (normalized with respect to $13 ms^{-1}$). C is the convergence $X 10^{-5}s^{-1}$ in the lowest 90 mb (normalized with respect to $9 X 10^{-5}s^{-1}$). Note that only kinematic variables are used in the current formulation of the mode parameter since these demonstrated the best discrimination skill. Thermodynamic parameters will be investigated more thoroughly in future research.

Results plotted in the box and whisker diagram in figure 7 show a large offset with no overlap between the 75th percentile rank for line cases and the 25th percentile rank for cell cases. The 75th percentile rank of the line cases are well below 1 while the 25th percentile rank for the cell cases are closer to 2. These results suggest the mode parameter in its current formulation has good skill in discriminating between situations where storms evolve into lines within 3 hours of initiation and those situations where storms remain cellular after 3 hours.

The type of initiating boundary also appears to play a role in the evolution of storms once they are initiated. Figure 8 is a plot of the mode frequency versus type of boundary. There is an overwhelming tendency for the storms that remained discrete longer than 3 hours to be associated with drylines and pre-frontal troughs. Cases where storms evolved into lines during this time frame were mostly associated with cold fronts. This might be due in part to the tendency for some cold fronts to be accompanied by stronger deep layer forcing than that associated with pre-frontal troughs and drylines.

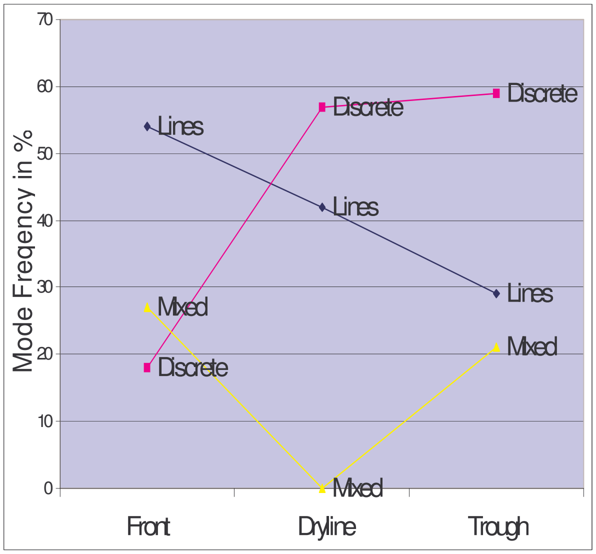

Figure 8. Mode frequency in %.

4. Conclusions and Future Research

Preliminary results suggest that the orientation of the 2-6 km or 2-8 km mean wind with respect to the initiating boundary and the component of 2-6 km or 2-8 km shear normal to the initiating boundary are good discriminators between those environments where storms remain discrete within the first few hours after developing versus those where storms evolve into lines for storms initiated along a synoptic boundary. It would appear that when the mean 2-6 km or 2-8 km flow and boundary are nearly parallel, the precipitation cascades and associated outflows of neighboring storms may merge and consolidate more quickly. Results also suggest that when the component of middle level shear normal to the initiating boundary is weak, upstream development of a cold pool may occur more readily with a faster transition to lines than when this component of shear is strong. The amount of low level convergence appears to discriminate, but to a much lesser degree. Stronger low level convergence would likely lead to the development of more storms which would in turn increase the chances for storm interactions. Other than geometry and convergence, the type of initiating boundary also appears to play a role. It appears that storms initiated along cold fronts generally have a greater tendency to evolve into lines more quickly than those initiated along pre-frontal troughs or drylines.

The results achieved so far remain preliminary, due mainly to the limited data set. As more data are accumulated within the next two years, more robust results are anticipated. This study only included kinematic variables as part of the mode parameter calculation. Additional sensitivity studies will be performed using various thermodynamic variables to assess their ability in conjunction with kinematic variables to discriminate between the types of mode evolution. A more in depth examination of the physical processes governing evolution of discrete modes into lines is also planned.

5. Acknowledgements

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