

Talking points for MCS teletraining session

Part. I Introduction

Slide 1 Title

Slides 2-3 Objectives

Part II Scale Characteristics and Climatology of MCSs

Slides 4-5 Climatology of mesoscale convective systems--hopefully explains why MCSs are important from a precipitation forecasting perspective. Kane et. al found that the composite precipitation patterns associated with various types of MCSs (based on the Maddox archetypes) were very similar but that the scale of the events differed. Synoptic and frontal type systems are typically larger than mesohigh type events. A study of MCSs over the Southeast by Geerts found that MCSs were more common in summer but were of larger scale and lasted longer during winter. This suggests that the scale and strength of the forcing may be one factor that determines the scale of an MCS.

Slides 6-7 Summary of moisture, stability and synoptic characteristics for the frontal and mesohigh Maddox et al Composites.

Slides 8-10 Maddox et al. 500-, 850mb and surface patterns for mesohigh and frontal archetypes. Also, climatology and composite sounding profile of mesohigh and frontal heavy rain/ff events.

Slide 11 Figure by Blanchard et al. indicating areas where weak inertial stability or inertial instability might lead to upscale growth of convection by enhancing the upper level divergence. One of the reasons why frontal and mesohigh type events often form near the axis of an upper level ridge may in part be due to the weak inertial stability found near the ridge. Region where there is strong anticyclonic curvature or anticyclonic shear are places where the inertial stability is weak.

Slide 12 This figure from Augustine and Caracena (1994) illustrates that the very largest scale, longest lived MCSs during their study were associated with stronger frontogenetical forcing than the smaller scale shorter lived MCSs. This again suggests that one of the factors that governs the size of the MCS is the scale of the forcing.

Part III. Movement and Evolution of MCSs

Slides 13-16 These figures are based on work done by Parker and Johnson (2000). These slides explain why there are three linear MCS archetypes. Which of the three archetypes that develops is dependent on the system relative wind field. Slide 16 shows the system parallel relative wind field (the circles) and system normal relative wind field (the arrows). The system relative wind field is critical to the evolution and movement of mesoscale systems. Later slides

will discuss how the system relative wind field can influence how the system moves.

Slides 17 Describes how the stratiform portion of the rainfall forms and what impact it has on the rear inflow jet and vertical motion field. For the trailing stratiform type MCS, front to rear flow helps generate new cells on the leading edge of the MCS and more stratiform precipitation on the trailing end.

Slides 18-19 These slides are taken from COMET MCS CBT module (COMET, 1999) and are based on some of Weisman's (1992) model simulations showing the balance between the cold pool and low level shear. Slide 18 is for stage 3 of the development of convection and is usually found with less low level shear than the balanced upright state shown on slide 19. On the latter slide a stronger cold pool is present. The development of the cold pool then helps fuel the rear inflow jet. The cold pool development also helps to strengthen the vertical motion within the region where the "stratiform" precipitation forms. The MCS simulations that develop the balance between the cold pool and shear generally lasted longer than the ones with a weaker cold pool. Recent work by Evans and Doswell (2001, Wea. And Forecasting) suggests that the storm relative shear may be more important than the cold pool in determining whether a linear MCS will be long lasting or not. Systems with strong system relative low level inflow on the east side of the system and weak storm relative flow at mid levels last longer than systems having weaker low-level storm relative flow.

Slide 20 Dumb guy thoughts on system movement. Slow moving systems produce more rain. For short range forecasts (0-1 or 2 hours). Extrapolation of radar and satellite imagery works reasonable well for forecasting movement for most cases. However, after an hour or two extrapolation rarely works well because systems do not merely advect at a constant speed. Non linear processes determine how they move. Always try to anticipate along which flank new convective cells will form. Which flank new cells develop along determines whether propagation effects will cause the convective system to move faster or slower than the mean flow of the cloud bearing layer. For longer time ranges model output provides a pretty good approximation of what the synoptic pattern will look like. However, the model probably will not handle smaller scale features well. The models also usually cannot handle propagation effects since the NMC models convective parameterization schemes and microphysical packages do not realistically simulate downdrafts. These downdrafts often play a role in focusing the low level convergence.

Slide 21 Propagation is influenced by a number of factors: 1) The cold pool and resulting outflow boundary. The speed of the gust front is relative to the temperature difference between the cold pool and air around it. However, trying to use this relationship operationally is difficult because of the lack of knowledge about the strength of the cold pool and the non-linear processes that help generate it. 2) Non hydrostatic pressure gradients and buoyancy gradients also play a role in determining the propagation since each plays a role in helping produce the rear inflow jet. Again, as a forecaster there is no real way to account for how these factors might influence system movement. 3) where the strongest low level moisture convergence and instability is located relative to the system. New cells will generally form in areas of strong moisture flux convergence and instability. When strong moisture convergence and instability is located upstream or upshear from the initial convection, the rate at which new cells form in this area of strong low level convergence will cause propagation to oppose the movement of the convection due to advection. 4) Storm or system relative winds play a role in determining where the strongest low level convergence and lifting will be located.

Slide 22 One of the best ways to anticipate whether propagation will slow or speed up a

system motion is to look at where the strongest low level convergence and instability is located in relation to the location of the initial convective development. Often where the low level jet is located will play a major role in determining where the strongest moisture and instability is located. If the airmass is moist and unstable on the downstream side of the system and if the low level jet is aimed at the leading edge of the convection then the strongest moisture convergence will be located on the leading edge of the convection. New cells will form within this area of moisture convergence. The rate at which the new cells form along the leading edge of the system will cause the system to move faster than the mean flow. Essentially, propagation effects cause the system to move faster than it would because of advection. The bottom figure shows the opposite case in which the position of the low level jet helps maintain the strongest low level convergence on the upstream side of the initial convection. Here propagation counters the movement due to advection. About 60 percent of the quasi-stationary convective systems are located in regions where the thickness lines splay out or are diffluent. About 40 percent of the cases occur where the thickness gradient and thermal wind do not change downstream.

Slide 23 The figure attempts to illustrate that the movement of a convection system is the sum of the vector describing cell movement and another vector describing the effects of propagation. This is essentially the basis for the Corfidi vector technique. In this case new cells forming on the upstream side produce a propagation vector that is almost anti-parallel to the vector described by the mean wind. Therefore, the resultant movement of the MCS is very small.

Slides 24-25 These slides are used to discuss the basis for the original Corfidi vector method. Slide 24 shows scatter diagrams indicating that the 850-300 mean wind speed and direction is a good approximation of the movement of individual cells during MCS initiation. In essence, a convective cell moves with the mean winds within the cloud bearing layer. Corfidi created two scatter diagrams showing that there was a high correlation between the 850-300 mean wind speed and direction and the actual movement of MCSs for Merritt's original data set. It is important to note that for convection with unusually low cloud tops using the 850 mb mean wind may be a poor approximation for cell motion. In addition, for potentially deeper clouds (EL levels higher than 300 mb), you may need to use 850-200 mb layer for mean wind calculations.

Slide 26 The next step is to find a way to approximate the propagation vector. The scatter diagram shows that the direction of propagation is antiparallel (in the opposite direction) to the low level jet. Note there were two significant outliers. The big question then became how to determine the magnitude of the vector. Corfidi reasoned that the stronger the low level jet, the stronger the area of low level convergence should be along the flank of the MCS being impinged upon by the jet. He therefore assumed that the propagation vector was equal to and of opposite sign as the low level jet. Shows fairly high correlations for speed and direction using Merritt's original data set. One important point to make is that most of Merritt's cases were large scale MCCs similar to those found by Maddox et al. The low-level jet found by Corfidi for the various cases was often not found at 850 mb. When using the technique look at sounding or forecast sounding, before defining the low level jet.

Slide 27 This describes the equation for the original "Corfidi" vectors (good for backbuilding situations).

Slide 28 This slide shows the structure of a convectively induced circulation. These type circulation have cyclonic vorticity in the mid levels and anticyclonic vorticity at upper levels. Convectively induced vorticity (Neddy Eddies) need to be monitored closely since they can

generate a new convection system with heavy to excessive rainfall the next day (or more often night) as long as the system is moving through a moist and unstable environment. In the proceeding example, we will look at a good backbuilding MCS case.

Slides 29-30 May 7, 2000 example of a convectively induced circulation that had new convection form the following night. The slide shows moisture and stability parameters from a nearby upstream sounding for this case. Note that the mean 850-300 mb relative humidity was very high and that the CAPE was positive but not overly impressive. The high relative humidity and modest CAPE favor efficient rain processes. The modest CAPE suggests that updrafts will be weak enough to allow long resident time within clouds to maximize collision coalescence. Large values of CAPE correlate to strong updrafts which allow less time for warm rain processes to occur. Thus, the updrafts might be strong enough to lose condensate from the top of the storm. The high mean relative humidity suggest that the convection will have lower cloud bases making easier to have a deep warm layer which is favorable for warm rain processes. Also the high mean relative humidity should minimize evaporation

- . Slide 31 Note on the loop of IR imagery how that convection develops near the center of the convection and then the vort moves east of where convection continues to redevelop. Question - What are possible reasons that convection might keep reforming to the west of the vort? Note that this MCS develops a similar structure to the leading stratiform and trailing convective type MCS.

Slide 32 Question about what type of linear MCS archetype is expected with this setup. Answer: B (leading stratiform because convergence keeps regenerating convection on SW side of system.)

Slide 33 Analysis of the 850 and 300 charts valid 00Z May 7. Note that a strong southwesterly low level jet is feeding towards the area where the convection developed. This jet should help hold the low level convergence on the southwest flank of the developing MCS. Such flow allows the rear to front flow often found with leading stratiform/trailing convection MCSs.

Slide 34 06 and 10Z surface analyses. Note that each shows an outflow boundary that remains stationary through the period.

Slide 35 RUC 850 wind and moisture convergence analyses at 06 and 10Z. Note that the moisture convergence along the outflow boundary remains stationary as a broad low level jet translates eastward. A broad low level jet can also play a role in modulating the scale of the MCS by helping produce a large zone of strong low level convergence.

Slide 36 Note on the radar loop how the convection keeps regenerating along the western edge of the convection even as the old cells advect away. These new cells form where the air is being lifted across the outflow boundary.

Slide 37 A time cross section of reflectivity from KLSX. The brightest reflectivities are found below the freezing level suggesting the potential warm rain processes. Whenever a forecaster notes that bulk of the brightest reflectivity is below the freezing level, then the normal ZR may significantly underestimate the rainfall rates. One possible exercise to conduct while showing the slide is to calculate the rainfall rate using the tropical versus normal ZR. Often, these type events have very low cloud bases and can have relatively low cloud tops. Therefore, the radar beam may overshoot tops if the storms are far from the radar site.

Also, note that the low centroids continue through the entire period suggesting an extended period of extreme rainfall rates.

Slide 38 Question on hourly rainfall rates. Best answer? We think you should estimate more >3 (D) because of the backbuilding nature of the event and the persistent Z centroids.

Slide 39 Shows total rainfall for the event (left) and half-hourly rainfall rates. Note that there was an extended period of 2 to 3 inch per hour rainfall rates. Such intense rainfall rates are rare at any given location. Yet in this case these rates persisted for an extended period.

Slide 40 Conditions favoring a slow moving or quasi-stationary MCS. When these conditions are met, it is usually better to use the original vector method to predict MCS movement.

Slide 41 Modifications to the vector approach. Corfidi (2001) suggested that the original vector technique seriously underestimated the motion of the squall line because it failed to account for propagation that occurs in the downshear direction. You should consider the direction of greatest system-relative convergence and the distribution of surface-based instability when applying the vector technique.

Slide 42 This slide shows an idealized gust front evolution. Note that at the leading edge of the gust front, if the airmass is moist and unstable, new cells will form because the system relative inflow on the east side. This is a favorable location for a derecho. However, also note that the western edge of the boundary could become parallel to the mean flow which could allow training of cells to occur. Sometimes, forward and quasi-stationary convective system can develop in fairly close proximity. The orientation of the gust front relative to the mean wind is important aspect to consider when/if a MCS transitions to a forward propagating structure (possible derecho).

Slide 43 Modified vector method. Essentially, this vector method says that if the airmass is unstable downstream of the initial convection, then a forward propagating MCS is a good bet. The resulting motion of the MCS is the sum of the mean wind and a system relative propagation vector that is dependent on the mean wind and the low level jet. For example, if the convection is moving east at 40 kts, the system is experiencing inflow of similar magnitude. Relative to the system, easterly winds are feeding into it. If the airmass is moist and unstable on the east side of the system, then the system relative inflow will produce moisture convergence along the leading edge of the convection. The inflow due to the system motion acts the same way that the low level jet worked in the original Corfidi vector method. System movement from west to east imparts a system relative east to west low level wind. To the moving system, this is analogous to having an east wind on the east side of the system. Remember in the original Corfidi vector method, the propagation vector was equal in magnitude but opposite in direction to the low level jet. In the revised technique, the system relative low level wind acts similarly. Therefore, the MCS movement vector from the original Corfidi method is therefore added to the vector that describes the mean wind (remember that the cold pool and initial convection are being advected by the mean wind at least in part because of the downward transport of momentum associated with the rear inflow jet). Essentially, in the revised vector method you double the mean wind and then subtract the low level jet from that sum. You are essentially adding the cell motion (mean wind) and system relative propagation vector (it is dependent on the mean wind and the low level jet).

One question always arises. When should a forecaster use the original technique and when should he or she use the revised technique? In general, when the airmass is moist and unstable on the upstream side and stable on the downstream side, the original technique should be used. If the airmass is moist and unstable downstream, then the revised method is more appropriate. However, when the airmass is unstable both downstream and upstream from the initial convection, either or both modes may develop. In that case, mode will likely be determined by the location of the greatest system-relative convergence.

Slides 44-47 A case of a forward propagating MCS that moved faster than the 850-300 mean wind and also moved faster than was predicted by the original Corfidi vector method. One question to ask is what level would a forecaster use to describe the low level jet. The green arrows are the vectors from the original vector method. Note location of surface theta-E ridge in central/southern OK.

Slide 48 Conditions favoring a forward propagating MCS. When these criteria are met, it is usually better to use the revised Corfidi vector method.

Part IV: Precipitation Distribution of MCSs

Slides 49-50 Show composites of the precipitation associated with the Kane et. al population of MCSs. Again, his MCS were generally similar to those found by Maddox et al. The horizontal line on each slide shows the path of the MCS as described by the centroid of the coldest cloud top temperature using a common enhancement curve. The heaviest precipitation usually falls on the south side of the path. Slide 50 shows the probability of 75 mm of rain based on the composites. Note the very low probability for the heaviest rainfall. This composite does not necessarily mean that there is a low probability of 3 inches of rain occurring somewhere within an MCS. Another explanation is that the very small scale of the 3 inch area makes it difficult for the areas to overlap. Therefore, the probabilities for 75 mm or 3 inches would remain small.

Slides 51-63 Research from the 1993 floods. Rainfall events were categorized by the size of the 3 inch areas that were analyzed. Forecast rules of thumb were tested. The scale of the heavier rainfall event at least in part seemed to be modulated by the relative humidity. Most of the larger scale heavy rainfall event occurred with mean RH values that were above 70% just prior to the development of the MCS. The heaviest rainfall events generally occurred when the axis of strong moisture convergence aligned parallel to the mean winds upstream from where the heaviest rain was reported. Composites of the heavy rainfall events are also shown.

Part V. The Exercise

Slides 64-109 MCS exercise. Ask forecasters questions about the various fields shown. For example, where would you expect strong upper-level divergence based on slide 69. Why? On slide 96 there is small area in west-central Oklahoma where backbuilding appears to be occurring. This is a chance to explain that in early stages of MCS development that the Corfidi vector method does not always work. The method works best for mature systems. My own experience is that convection out ahead of the main MCS seems to have a better chance at having a period of backbuilding prior to organizing into a system.

How do the PWs over Oklahoma on slide 72 compare to those found by Maddox et al. for frontal type MCCs? If an MCS developed over eastern New Mexico how would the east winds at 850 affect its movement?

On slide 80, what does the CIN field suggest about the potential for convection in Kansas? Texas? Oklahoma?

On Slide 83 what is the significance of the low surface dewpoint depressions over Oklahoma? Would you expect high or low cloud bases? What does it imply about precipitation efficiency?

Slide 89, what does the hodograph say in terms of severe potential? On the right hand side, the Corfidi vector technique is using the original method. Based on the location of system-relative convergence and instability, would you expect the resulting MCS to move faster or slower than the vectors shown on this figure?

What is the significance of the east 850 mb winds over OK? If any MCS developed in the TX panhandle would you expect it to move faster or slower than the mean winds? What mode of development would you expect, a leading or trailing stratiform MCS?

Does the LAPS data at 04Z suggest that the MCS will turn to the right or continue moving basically eastward?

Part VI. Summary

Slides 109-110 Summarize the exercise and the entire lesson. MCSs remain very complex. A number of factors govern their evolution, movement and precipitation shield.

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