P4.5 STUDY OF MIDWESTERN MESOSCALE CONVECTIVE SYSTEMS USING NEW OPERATIONAL NETWORKS

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1. INTRODUCTION

Loehrer and Johnson (1995) recently determined from a study of 16 mesoscale convective systems (MCSs) during OK PRE-STORM (Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central, 1985) that despite the wide variety of initial precipitation structures of the MCSs, repeatable patterns developed in 75% of the cases during their mature-to-dissipating stages. The precipitation structure at these later stages can be best described as asymmetric, following the definition of Houze et al. (1990). During earlier stages, a symmetric pattern (Houze et al. 1990) was observed in some, but not all, of the MCSs. An illustration of these patterns, along with the typical surface pressure fields is shown in Fig. 1. Three prominent surface pressure features are found: the pre-squall mesolow, the mesohigh and the wake low. These features are consistent with, but extend the earlier findings of Fujita (1955) and Pedgley (1962) to include the relationship between the pressure fields and radar echoes. It was emphasized in Loehrer and Johnson (1995) that while the symmetric and asymmetric classifications of Houze et al. (1990) were confirmed by the PRE-STORM data, these patterns characterize precipitation structures at different stages of the life cycle rather than representing specific types of MCSs.

Since the PRE-STORM results are for a limited number of cases, it is important to see if the results can be extended to additional cases and to other years. With the advent new operational observing networks in the United States, e.g., WSR-88D radars and surface mesonetworks, it now becomes possible to investigate the detailed surface pressure patterns within MCSs without executing a costly field project. One issue of particular interest is whether or not the evolution of MCSs into asymmetric structures – namely, the development of a precipitation pattern characterized by a maximum of stratiform rainfall and an accompanying intense wake low on the northern end of the system in the later stages of the MCS life cycle – is a pattern of behavior that can be generalized beyond the PRE-STORM results (Loehrer and Johnson 1995). In this paper we combine data from the Oklahoma Mesonet (Brock et al. 1995) with NEXRAD data to determine the evolution of the surface pressure fields accompanying MCSs that crossed Oklahoma during May-June 1995. Although only a few cases in early May have been analyzed at this writing, results for all of May and June will be presented at the conference.

2. DATA AND ANALYSIS PROCEDURES

The surface data in this study are from the Oklahoma Mesonet, an automated mesonetwork of 111 stations covering the state of Oklahoma (Brock et al. 1995). At least one Mesonet station is located in every county (Fig. 2), with an average spacing of
Figure 1 Conceptual model of the surface pressure, flow and precipitation fields associated with the (a) symmetric and (b) asymmetric stages of the MCS life cycle. Radar reflectivity field is adapted from Houze et al. (1990). Levels of shading denote increasing radar reflectivity, with darkest shading corresponding to convective cell cores. Pressure is in 1-mb increments. Small arrows represent the surface flow. Lengths of the arrows are proportional to the wind speed found at their center. Large arrows represent the storm motion.

Location of Mesonet Sites
(Land Ownership)

- OSU / OU Research (18)
- Academic / Foundation (11)
- Federal / City / State (16)
- Airport (11)
- Privately Owned (52)
- ARS Micronet (45)
The observations consist of 5-min averages of temperature, humidity, barometric pressure, wind speed and direction, rainfall, solar radiation and soil temperature. Of primary interest to our study are the measurements of pressure. The pressure sensor used is a Vaisala PTB202 barometer with a quoted inaccuracy of 0.4 mb.

One of the objectives of this study is to document in detail the pressure fields within mesohighs and wake lows. To remove the effects of elevation, pressures have been reduced hydrostatically (using the surface virtual temperature) to a common elevation (the average elevation of the mesonet stations, 390 m). Data from one site, Ketchum Ranch, were not used in subsequent analyses due to errors in pressure measurements. Since intense pressure gradients can exist between mesohighs and wake lows (up to 5 mb (10 km)$^{-1}$ and greater), it is essential to make use of the 5-min pressure data in the analyses. To do this, a time-space transformation procedure has been applied to data 15-min either side of a central time using the velocity of the convective system as determined by radar data (following Loehrer and Johnson 1995). This procedure produces data points aligned on both sides of each station location. The entire field is then subjected to the Barnes (1964) objective analysis scheme.

The radar data used in this study, a composite of the base-scan reflectivity fields from WSR-88D sites in Oklahoma and surrounding states, have been provided by the Oklahoma Climatological Survey.

3. MAY 5-8 CONVECTIVE EVENTS

A total of five MCSs traversed Oklahoma during the period 5-8 May 1995. Two of them will be investigated in this section.

3.1 May 6 case

A surface map at 0000 UTC on 6 May is shown in Fig. 3. A major low-pressure center was located over the Rocky Mountain states with a large high over the upper Midwest. Strong southeasterly flow existed over much of the Plains, except in a region north of a stationary front over central Texas where the flow was easterly.

A north-south band of convection extending from north-central Oklahoma to central Texas at 0210 UTC (Fig. 4) was moving toward the east at $\sim 15 \text{ m s}^{-1}$. North of the stationary front the precipitation was less intense and highly stratiform in character, consistent with other studies of MCSs in frontal-overrunning situations (Smull and Augustine 1993). South of the front, the precipitation was much more convective, with a pattern of a bowed, leading convective line and a trailing stratiform precipitation region at the northern end. The precipitation structure south of the front resembled the asymmetric pattern of Houze et al. (1990).

Figure 3: Surface map at 0000 UTC 6 May 1995.

Figure 4: Base-scan radar reflectivity at 0210 UTC 6 May 1995. Shadings correspond to reflectivity thresholds of 18, 30, 41, 46 and 50 dBZ.

The surface pressure field over Oklahoma at 0210 UTC is shown in Fig. 5. The most dramatic feature at this time was a mesohigh-wake low couplet associated with the north-south precipitation band. The mesohigh was within the region of heaviest rainfall with several wake lows immediately to the rear of the precipitation band. The most intense pressure gradient appeared to "hug" the back edge of the strati-
form rain area, consistent with the findings of Johnson and Hamilton (1988) and Loehrer and Johnson (1995). The most intense wake low was at the far southern boundary of the network and therefore could not be fully resolved by Oklahoma Mesonet data. Nevertheless, the portion that was resolved revealed a pressure gradient exceeding 5 mb (20 km)\(^{-1}\). Five-minute average surface winds within this intense gradient at Ringling in southern OK (Fig. 2) were 18.4 m s\(^{-1}\) from 092°, with a peak gust of 23.7 m s\(^{-1}\).

Figure 5: As in Fig. 4, except 300-m pressure contours are included (0.5-mb intervals).

The appearance of an intense wake low in southern Oklahoma – at the far northern end of the MCS in Texas (Fig. 4) – is generally consistent with the conceptual model for asymmetric MCSs shown in Fig. 1. Unfortunately, the absence of high-resolution pressure data in Texas precluded a complete analysis of the pressure field for the entire squall-line system.

### 3.2 May 8 case

A surface pressure map for 0000 UTC 8 May is shown in Fig. 6. A cold front extended out of a low center in eastern Colorado with an east-west warm front across Oklahoma. A pre-frontal squall line is denoted in the warm, moist southerly flow ahead of the cold front.

The base-scan radar reflectivity data from the WSR-88D sites at 0045 UTC (Fig. 7) shows an extensive north-south squall line from Kansas to Texas [the line actually extended as far north as Nebraska]. The squall line has the appearance of being more mature at its northern end, where there is a trailing stratiform precipitation region separated from the leading convective line by a weak-reflectivity transition zone. At the far southern end in Texas there is a broken line of intense convective cells with very little trailing stratiform precipitation. At this time the squall line was moving to the east at \(\sim 13\) m s\(^{-1}\).

Figure 6: Surface map at 0000 UTC 8 May 1995.

Figure 7: Base-scan radar reflectivity at 0045 UTC 8 May 1995. Shadings correspond to reflectivity thresholds of 18, 30, 41, 46 and 50 dBZ.

The surface pressure field at 0045 UTC (Fig. 8) shows several pre-squall lows, mesohighs (behind the convective line) and trailing wake lows. The pattern is similar to the 6 May case, except the pressure gradient to the rear of the stratiform region is not as
intense, at least at this stage of the life cycle. The strongest gradient was at the northern portion of the domain, where the intensity of the stratiform precipitation was greatest. Therefore, this pattern somewhat resembles the asymmetric structure in Fig. 1. On the other hand, since the variation in the gradient along the back edge is not significant (perhaps in part because the squall line was exceedingly long), it also has some of the characteristics of a symmetric MCS (Fig. 1). In particular, the 8 May squall line bears a close resemblance to the 10-11 June 1985 PRE-STORM squall line that has received extensive study (e.g., Johnson and Hamilton 1988).

Figure 8: As in Fig. 7, except 390-m pressure contours are included (0.5-mb intervals).

4. SUMMARY AND CONCLUSIONS

Oklahoma Mesonet and WSR-88D data have been used to document the detailed surface pressure fields accompanying two intense squall lines that occurred on 6 and 8 May 1995 over the central United States. Both systems were characterized by leading convective lines and trailing stratiform precipitation regions. In addition, both exhibited surface pre-squall lows, mesohighs and wake lows. The pressure fields generally resembled those depicted in the schematic for the asymmetric MCS structure shown in Fig. 1. However, the lack of a high-resolution surface mesonet in states adjacent to Oklahoma limits the ability to fully describe the entire pressure field for these large MCSs. Nevertheless, much of the life of MCSs can be sampled by the Oklahoma Mesonet and further work is underway to investigate other systems that traversed the Oklahoma region during May and June 1995.

5. ACKNOWLEDGMENTS

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6. REFERENCES


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