P5.23 OBSERVATIONS OF THE GREAT PLAINS DRYLINE UTILIZING MOBILE MESONET DATA

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1. INTRODUCTION

The Great Plains dryline (DL) frequently is a focal region for initiation of deep moist convection (Rhea 1966; Bluestein and Parker 1993) and is of interest for both forecasting and convective initiation issues. The DL has been the focus of extensive study in past decades. A plethora of observational (e.g., NSSP Staff 1963; Bluestein 1990; Parsons et al. 1991; Hane et al. 1993, 1997; Crawford and Bluestein 1997; Atkins et al. 1998) and numerical (Schaefer 1974; Sun and Wu 1992; Ziegler et al. 1995, 1997; Grasso 2000) studies have revealed a varying range of thermodynamic and kinematic properties. The research has provided insight into the behavior and structure of the boundary.

Through the use of in situ observations obtained from research aircraft and mobile atmospheric soundings along a north-south oriented DL, Ziegler and Hane (1993) produced a conceptual model of the afternoon dryline (also see Fig. 14 Ziegler and Hane 1993). In the paper, the authors demonstrated that two parent airmasses bound the DL; a relatively hot, dry quasi-homogenous airmass west of the DL and a cooler, moist airmass east. The airmass east of the DL is either homogenous or well mixed. The interface between the two air masses is termed the mixing zone. Mixing occurs over a horizontal finite width on the order of 10 km. The airmass thermal properties within the mixing zone are composed of thermal variables characterized by mixtures of the two parent airmasses.

The 1999 field investigation, (VORTEX) and that in 2000, (MOCISE) addressed, in part, questions pertaining to the thermodynamic variability along surface boundaries. Emphasis was placed on sampling the DL. One DL case that occurred in west Texas on 10 June 1999 is presented herein.

Mobile mesonet (MM; Straka et al. 1996) data analysis indicates the mixing zone across the DL was highly variable, comprised of a series of large horizontal moisture gradients ranging in spatial increments of 10 km down to mere tens of meters. Subtle variations in temperature and buoyancy existed. Several surface mesoscale circulations were observed along the DL. Of interest, vortices were sampled and/or observed concurrently with a strengthening of moisture gradients as well as a deceleration of DL movement to nearly stationary.

2. DATA AND RESULTS

Synoptically, a broad mid- and upper-level long-wave trough was located over the western U.S. Several embedded short-wave troughs rotated around the trough during the day. West Texas lay west of a departing negatively tilted short-wave trough and under a region of westerly mid- and upper-level flow that increased with the approach of a 300 mb, 75+ kt jet maximum along the base of the long-wave trough. The 1200 (all times UTC) 850 mb analysis indicated dewpoints >10°C were present west of Amarillo (hereafter AMA) and Midland, TX, and into southwest KS.

Convection from the previous night produced numerous outflow boundaries over the Texas Panhandle and northern New Mexico. A quasi-stationary front located along the Red River Valley of Texas provided a focal area for convective initiation throughout the day. Dewpoints of >8°C remained in place across eastern New Mexico until early afternoon. By 2000, a surface trough developed over the plains of eastern New Mexico, with a mesoscale DL about 250 km in length collocated within the trough. The DL extended south from the point at which the DL intersected an outflow boundary (OFB-3) north of Clovis (CVS), to northwest of Hobbs, NM.

a. Mobile Mesonet observations

Three MM and a M-CLASS van (Rust et al. 1990) equipped with a mesonet departed AMA at 1530 and proceeded southwest in the direction of the Texas/New Mexico border. Before encountering the DL, the MMs intercepted OFB-1 (Fig. 1) at 1727, where the air temperature increased ~1°C and dewpoints decreased, ~1°C, with a slight veering of the winds. The MMs intercepted the developing DL oriented north-south at 1830, ~10 km west of Friona, TX, on U.S. Highway 60. The highway intersected the boundary at an ~45° angle. The orientation and lack of adequate secondary roads around Friona prevented the MMs from performing transects normal to the DL. Transects were performed almost continuously at speeds between ~18 m s^{-1} and ~2.24 m s^{-1}. Land use bordering the highway varied between non-irrigated agriculture and commercial development. Transect locations were on the geological feature called the Caprock where elevation changes were minimal.

During the first hour of MM operations that began at 1830, moisture differentials along the DL were initially small; 5ºC over 4 km. The DL moved slowly east at ~2 m s^{-1}. Based on visual cloud observations and satellite imagery, the DL intersection with OFB-1 was ~40 km north of Friona, TX.

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By 1940, the observed moisture gradients began to collapse in scale (Fig. 2), concurrent with 1-3 km east-west oscillations in the location of maximum moisture gradients. These oscillations persisted for several hours and moisture gradients continued to increase throughout the afternoon. Concurrent with the collapse in the scale of the mixing zone, the DL was observed to become nearly *stationary* in its forward propagation.

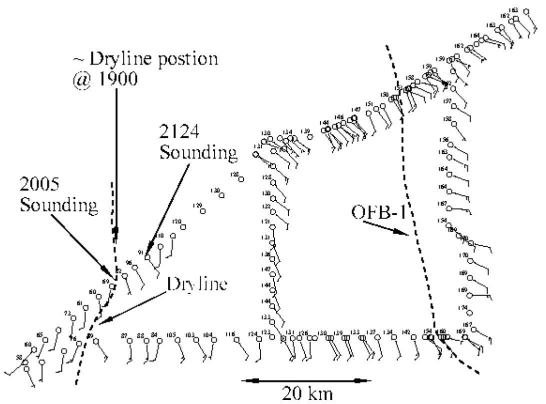

Figure 1. Surface composite for 1711-1900 UTC 10 June 1999 with mobile mesonet dewpoint temperature (tenths °C) and winds, pertinent boundaries, and locations of two M-CLASS soundings discussed. Winds in knots with one full barb, and one half barb equal to 10, and 5 knots, respectively. The image should not be viewed as if the surface data and features were steady state.

Cumulus (CU) fields west of a DL have been observed in previous DL studies (Ziegler and Rasmussen 1998). Similarly in this case, at ~1930 a small field of CU was observed to develop and persist behind the DL ~30 km west-northwest of the DL (Fig. 3). CU bases were visually estimated ~2.5 km AGL, at a level higher than cloud base observation near CVS at 2000. At 2000, CVS, located 62 km southwest of Friona and 56 km west of the DL, reported few clouds at 1.5 km AGL.

WSR-88D data for AMA at 1957 depicted the location of several outflow boundaries. No radar fine line was present, as there were no detectable echoes associated with the DL. The lack of a fine line suggested that either convergence at the DL was shallow, convergence aloft was rather weak, or simply a lack of scatterers. However, a line of small, spatially isolated cumulus clouds (CU) ~3 km AGL were observed by the MM operators. These CU were directly above the interface of the dry-moist axis of the developing DL.

At 2008, a cyclonic eddy was resolved in the MM data (Fig. 4) with a horizontal scale of about 2000 m. Based on the data, the vortex appears to have been in the process of an occlusion with respect to the advection of air from the moist side of the DL to the dry side and vice versa. The vortex was unique within the 10 June 1999 MM data set. Dewpoint gradients immediately downstream of the vortex began to strengthen sharply (~9°C km^{-1}). 12°C dewpoints (the largest recorded MM values of the day along the DL) were sampled immediately downstream of the eddy. Upstream of the asymmetric vortex, moisture differentials remained large. Of interest, the eddy appeared concurrently with strengthening moisture gradients and the approximate time when the DL had slowed to nearly stationary.

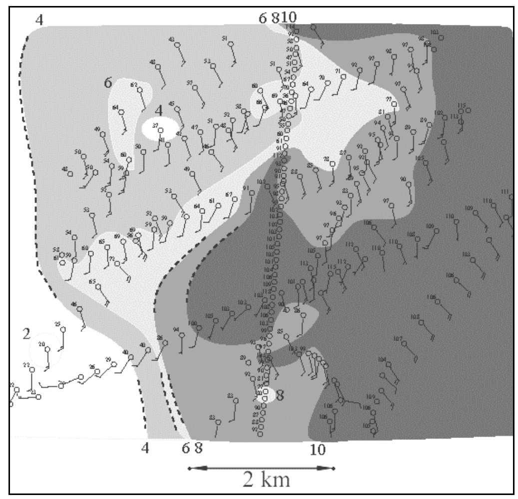

Figure 2. Subjective analysis of mobile mesonet dewpoint temperature (tenths °C) observations across the dryline at 1938-1956 UTC on 10 June 1999. Observations are 18-sec averages (3 observations) plotted every 18 sec using time-to-space conversion with a motion vector from 185 at 6.0 m s^{-1}. Isodrosotherms shaded every 2°C. Winds as in Fig. 1. Dashed contours are used in regions where the analysis is less certain owing to low observation density. Some observations have been omitted to improve figure clarity. The M-CLASS mesonet winds were in error and have been omitted.

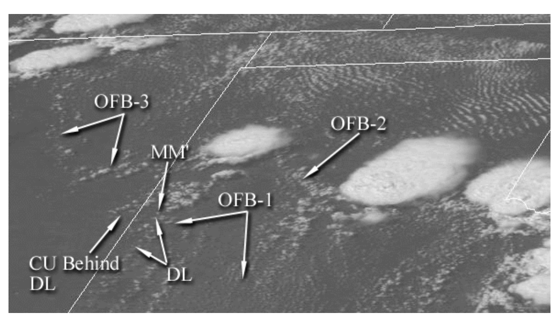

Figure 3. *GOES-8* visible imagery for 2025 UTC 10 June 1999 with relevant surface boundaries, features, and mobile mesonet location depicted.

Fairly constant moisture gradients on the order of ~6°C km^{-1} would persist for the remainder of the MM transects. Surface wind speeds along the DL remained nearly constant during that time. The moisture gradient was perturbed at times by pockets of dry air from west of the DL that had mixed to the surface (Fig. 5).

Concurrent with the increased moisture differentials, large dust devils were observed by the MM crew, moving northward along the axis of maximum moisture gradient at ~6 m s^{-1}. Some of these dust devils persisted for tens of minutes. The estimated diameters of the largest dust devils were ~80-100 m and ~1+ km deep. Many of the

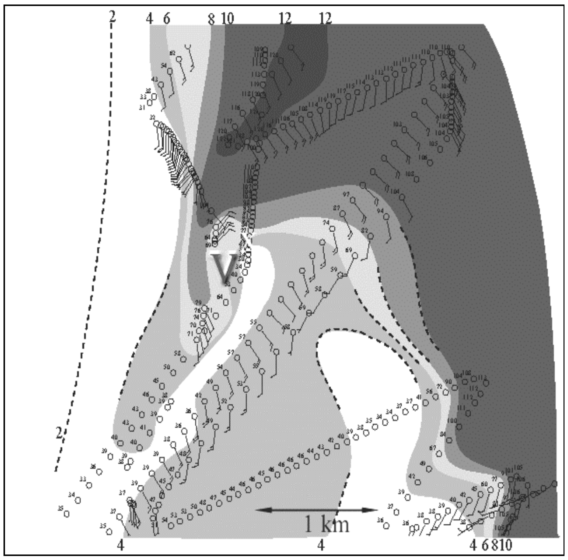

Figure 4. Subjective analysis of mobile mesonet dewpoint temperature as in Fig. 2 except for 2004-2020 UTC. Observations plotted every 6 sec. The vortex had a horizontal scale of approximately 2000 m. The *X* denotes location of 2005 sounding release point.

12 observed dust devils were not collocated or visually connected with individual CU. Had CU been collocated with the largest dust devils, some individuals might have been tempted to label these vortices as landspouts. Based on visual observation by the MM crew, the line of CU directly over the moisture axis and dust devils quickly began to deepen vertically into narrow towering cumulus clouds (TCU), yet remained spatially isolated. A large area of cumulus congestus developed and persisted throughout the remainder of the afternoon, ~35 km north of the MMs, as they continued transects of the DL. The location of the cumulus congestus was presumed to correspond with the DL intersection with OFB-1. Visually, the dust devils appeared to travel toward the congestus updraft base. Additionally, at 2045, the DL resumed eastward movement at ~2.0 m s^{-1}.

The largest sampled moisture gradient was encountered over open country at ~2100. Over a 185 m distance, a 10°C dewpoint change was sampled as a MM traveled at ~2.25 m s^{-1} across the DL (Fig. 6). The associated equivalent potential temperature differential was ~15K. No vortex was resolved in the data at this time.

The lowest MM dewpoint temperature occurred at 2100, –0.6°C. In addition, at 2100 in CVS (now at a distance of ~58 km west of the leading edge of the DL), the dewpoint measured was 1.0°C. The CVS dewpoint readings oscillated between –1.0°C and 2.0°C for the remainder of the afternoon with a southwest wind of >13 kt. The fact that these well-separated observations behind the dryline contained similar dewpoints suggests that the MM was sampling the pre- and post-dryline airmass, and that at the location of the MMs along the DL, the mixing zone had collapsed to tens of meters.

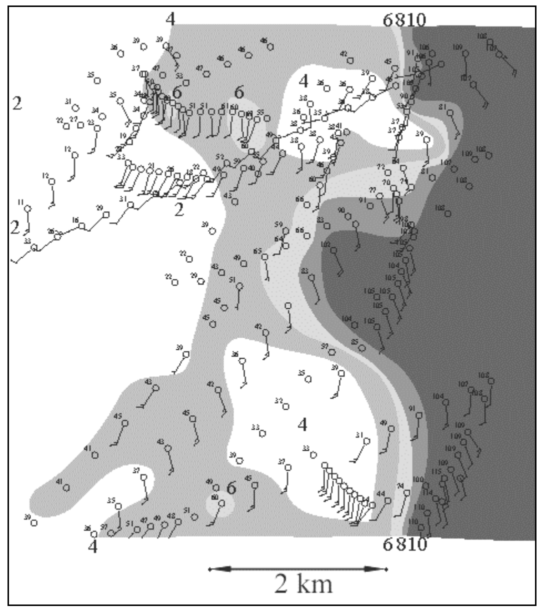

Figure 5. Subjective analysis of mobile mesonet dewpoint temperature as in Fig. 2 except for 2020-2033 UTC 10 June 1999. Note the tremendous moisture variability west of the largest moisture gradient.

Other large thermodynamic gradients sampled along the DL on 10 June 1999 included the largest θ differential, ~1.1°C over 500 m. The largest θ_v differential (1.1K km^{-1}) was collocated with the θ gradient. Thermodynamic gradients were larger than those found in some earlier DL studies: θ_v, 1.5 K per 6 km; q, 3 g kg^{-1} across 5 km (e.g., NSSP Staff, 1963; Ziegler and Hane 1993; Crawford and Bluestein 1997; Atkins et al. 1998; Ziegler and Rasmussen 1998). It cannot be refuted that yet larger thermodynamic differentials might have been sampled had the MMs performed longer transects east of the DL. However, given the temperature and moisture homogeneity on either side of the DL, it is believed the differentials would not have varied much from sampled values.

By 2200, 5 dBZ reflectivity echoes were detected in association with the DL. Deep, moist convection initiated in an area bounded by OFB-1 and OFB-2. Two supercells developed and persisted for over an hour as they moved adjacent to and along OFB-2. It was also ~2200 when the CU field west of the DL was observed to have dissipated completely.

Shortly after 2200, the DL began to surge eastward at ~8 m s^{-1}. As the DL mixed east, the moisture gradient weakened to ~4°C km^{-1}. The TCU dissipated with few CU remaining along the leading edge of the DL.

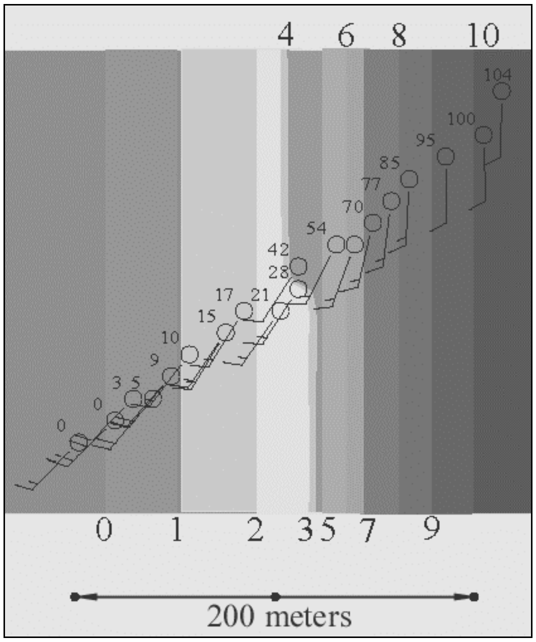

Figure 6. Mobile mesonet dewpoint temperature (tenths °C) and wind observations across the dryline at 2100 UTC 10 June 1999. No time-to-space conversion was used. Observations are 18-sec averages (3 observations) plotted every 6 sec. The mobile mesonet was traveling northeast at ~2.6 m s^{-1}. Isodrosotherms shaded every 1°C. Winds as in Fig. 1.

b. M-CLASS data

On 10 June 1999, six M-CLASS soundings were released. Two soundings launched in close proximity to the DL (Fig. 1) are discussed herein. The 2005 sounding (Fig. 7) was released directly within the dryline mixing zone and the northern edge of the vortex. A shallow, superadiabatic layer was detected above the surface. A mixing ratio of 5.2 g kg^{-1} was measured at the surface. A dry adiabatic layer extended from above the superadiabatic layer to ~600 mb. The sounding data resolved a large variation in moisture through the lowest ~75 mb depth of the boundary layer.

The 2124 sounding (Fig. 8), was released ~1.5 km east of the eastward propagating dryline. Compared with the 2005 sounding, there was greater uniformity and depth of moisture, now at 775 mb. An elevated residual layer from 550-750 mb had advected west-to-east over the surface dryline and moist layer, and was similar to conditions west of the dryline.

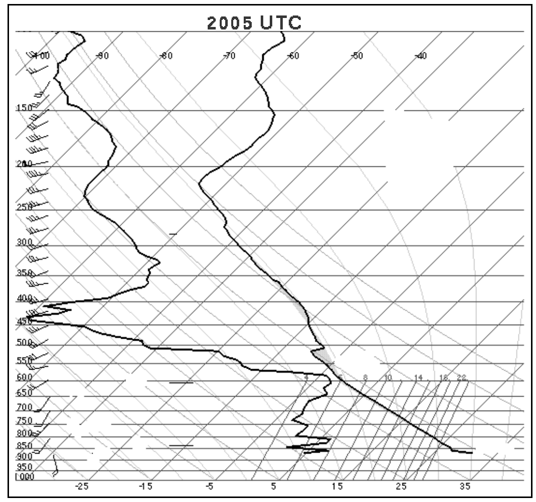

Figure 7. 2005 UTC M-CLASS sounding in skew *T*-log *p* format for 10 June 1999 released within the dryline mixing zone, approximately 0.75 km west of the large surface moisture differential. Winds as in Fig. 1.

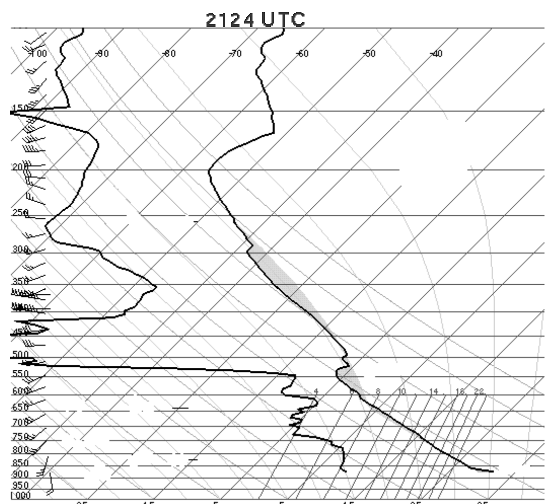

Figure 8. M-CLASS sounding as in Fig. 8 except for 2124 UTC 10 June 1999. The sounding was released approximately 1.5 km east of the dryline.

3. DISCUSSION

On 10 June 1999, a markedly different vertical moisture profile was observed by the 2005 sounding released within the mixing zone (Fig. 7), than that observed by the 2124 sounding released ~1.5 km east of the DL (Fig. 8). The 2005 sounding data resolved a large variation in moisture through the lowest ~75 mb layer, especially as opposed to the greater uniformity and depth of moisture east of the DL revealed by the

2124 sounding. Given that the surface dryline was oscillating east-west (Fig. 2), perhaps the same type of oscillation was occurring and the sonde passed through the dryline several times. Or perhaps the sonde passed through plumes or bubbles of air with larger moisture content consistent with previously proposed mixing hypotheses.

Several vortices were encountered along the DL during these investigations. What ramifications, if any, they have for convective initiation remains in question. Ziegler and Rasmussen (1998) suggest that, in order to form deep convection along a DL, moist boundary layer air parcels must be lifted to the LCL and LFC prior to leaving a mesoscale updraft. It is possible that vortices along the DL play a role in the production of localized updraft enhancement. Further, it is known that helical flows feature suppressed turbulence (Andre and Lesieur 1977; Levich and Tsiomber 1983), so it is possible that vortices embedded in the dryline are protected from mixing by virtue of their rotation.

Small spatially isolated CU were observed to develop, and eventually grow vertically into TCU before dissipation. What processes were protecting isolated updrafts that produced the CU from dilution along the DL? Atkins et al. (1998) presented evidence that the DL contains tremendous horizontal variability in the along-line direction. They hypothesized that the variability was owed to the interaction of horizontal convective rolls with the DL. At the point where horizontal convective rolls intersected the DL, localized updrafts are enhanced and clouds are initiated. On 10 June 1999, data were not collected in the horizontal along-line direction. Furthermore, on 10 June the presence of horizontal convective rolls was unverifiable: the DL was too distant from the AMA or LBB WSR-88D to resolve horizontal convective rolls that may have been in the DL vicinity.

Lastly, Ziegler and Hane (1993) and Ziegler and Rasmussen (1998) produced conceptual models of the DL during the afternoon and early evening. The former authors have defined the horizontal length scale of the DL to be on the order of 10 km, while the latter, 1-10 km. On 10 June 1999, the DL horizontal moisture gradient at 3 m AGL collapsed down to tens of meters at the location of the MMs. The data collected in this study supports the defined mixing zone length of the referenced scale model concept. The smaller surface length scale across the DL on 10 June is attributed to the more detailed temporal and spatial sampling by MMs as compared with the instrumentation utilized in previous DL studies, as well as the possibility that near the ground, smaller turbulent length scales allow for a smaller mixing zone width.

4. CONCLUSIONS

MM observations performed across-line DL sampling on 10 June 1999. MM data analysis demonstrated that the mixing zone across the DL was highly variable, comprised of a series of large horizontal moisture gradients ranging in spatial increments of 10 km down to mere tens of meters. In addition, a cyclonic surface mesoscale circulation was observed along the DL with a horizontal scale of ~2 km. The vortex was sampled concurrently with the time when moisture gradients across the DL became very large (9°C km^{-1}) and the DL was nearly stationary. Numerous visually strong, persistent dust devils greater than 30 m in diameter were observed moving along the moisture differentials. Observed CU along the DL were first spatially isolated and later became TCU before dissipation.

The largest sampled horizontal across-line dewpoint gradient was 10°C over 185 m with an associated theta-e differential of 15K. The largest temperature gradient measured 1.1°C over 500 m with a θ_v gradient on the order of 1.1K over 1 km along the leading edge of the DL. Strong vertical variations in moisture existed.

To address the questions presented herein and as necessary preliminary work prior to IHOP in 2002, further sampling efforts are planned in order to continue MM DL investigations.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Available upon request.