P5.24 OBSERVATIONS OF THE DCVZ USING MOBILE MESONET DATA

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1. INTRODUCTION

During the summer of 1998, the National Severe Storms Laboratory (NSSL) conducted a small field program in the western High Plains of Colorado. One of the program's primary objectives addressed the issue of convective initiation. The investigation was designed to document surface thermodynamics, kinematics, and flow structures embedded within boundaries. This objective was achieved to a limited degree through the use of two data collection systems mounted on vehicles, dubbed the mobile mesonets systems (MM). A complete discussion of the capabilities of the MM can be found in Straka et al. (1996). One motivation for presenting these data is to illustrate the tremendous capability of the mobile mesonet to resolve features at scales heretofore indistinguishable in atmospheric research. The MM sampled a variety of boundaries, including the Denver Convergence-Vorticity Zone.

The Denver Convergence-Vorticity Zone (DCVZ) develops as southeast low-level flow interacts with an east–west ridge known as the Palmer Divide (located between Denver and Colorado Springs), and the north-south axis of the Rocky Mountains Front Range. The resulting wind field is a gyre located near the city of Denver, with a region of enhanced vorticity and convergence usually extending to the northeast (Szoke et al. 1984; Szoke and Brown 1987). Previous studies of the DCVZ revealed rotational instabilities as vertically oriented vortices 1-4 km in diameter flowing along the boundary (e.g., Wilson et al. 1988; Szoke and Brady 1989; Wakimoto and Wilson 1989; Wilczak and Christian 1990; Wilson et al. 1992). A study by Roberts and Wilson (1995) demonstrated that the vortices had a wavelength of ~4-5 km.

Eight separate DCVZ events were investigated by the MM during the summer of 1998. Based on the observations, the boundary varies in horizontal extent at measurable scales from ~100 m to a region several km across. Observations also yielded numerous cyclonic eddies traveling along the boundary, ranging in size from 200 m to 4 km in diameter. Of the eight events, a total of 11 vortices were sampled by the MM. One case in particular, occurring on 16 July 1998, is presented herein, documenting significant variations amongst the eddies and moisture gradients sampled.

2. DATA AND RESULTS

On 16 July 1998, a Denver Cyclone developed, having a pronounced circulation by the late morning hours. A DCVZ became established in early afternoon east of Denver and was detectable on radar as a region of enhanced reflectivity that ran roughly NNE-SSW (Fig. 1). In this case, the DCVZ remained nearly stationary throughout the afternoon with small, spatially isolated cumulus clouds developing along and immediately east of the boundary. During the MM intercept, deep moist convection did not occur; thus, the boundary was not affected by thunderstorm outflow.

The MM operated on U.S. Highway 36 ~15 km east of Byers, CO. At this particular location the terrain had only minimal variations in elevation. Data were collected in a continuous series of two-vehicle ~18 m s^{-1} transects over a period of nearly two hours. Transect legs were ended 0.5 to 1.6 km to either side of the boundary. The 18 m s^{-1} vehicle speed was selected to adequately resolve larger eddies. Individual MM passes through the convergence zone revealed a complex structure that varied rapidly with time. The gradient of moisture exhibited a mixing ratio change of 8 to 11 g kg^{-1} within only a few hundred meters. This moisture differential was similar to that found by Wilson et al. (1992; 8 to 10 g kg^{-1} over a 1 km distance). However, the gradient present on 16 July was much larger. The temperature gradients across the DCVZ were 2ºC 15 km^{-1}, with warmer temperatures on the dry side of the boundary yielding a virtual temperature differential of 2ºC. A horizontal wind shift from southerly to northerly occurred over distances of less than 100 m. Analyses of the entire time series for the event revealed six eddies, sampled as they progressed northward along the DCVZ. Five of these circulations are analyzed and discussed below.

Eddy #1, 2057 UTC (Fig.2). This large eddy (~3 km) was relatively poorly sampled, given the lack of spatially dense observations. Additional MM would have allowed finer scale sampling.

When compared to subsequent vortices, the circulation appeared to be embedded in an area of higher dewpoint values. Because a vortex straddling dry and moist air would tend to produce a mixture of the two airmasses, it is likely that this particular vortex originated in moist air.

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Eddy #2, 2137 UTC (Fig. 3). This eddy had a horizontal scale of ~1500 m and had progressed partially through an "occlusion" process with respect to the advection of air from the moist side to the rear and vice versa. An examination of virtual potential temperature (θ_v) revealed uniform conditions +/- 0.5 K for the vortex. This observation was consistent in all vortices sampled. Additionally, the vertical vorticity associated with the eddy was ~1.5 x 10^{-2} s^{-1}. Vorticity was estimated as twice the velocity differential associated with equivalent solid body rotation.

Eddy #3, 2149 UTC (Fig. 4). This is an example of a relatively small vortex with a diameter of < 500 m. The eddy was embedded in a very large dewpoint differential (6ºC over 500 m), suggesting it was a “young” vortex, i.e., one that had not had sufficient time to "occlude" to any significant degree. The reduced size of this vortex and the degree of occlusion compared with the previous two circulations, leads to a natural question: Do small vortices grow upscale along the DCVZ, or do large vortices generally contract; or do both processes occur? Furthermore, what is the temporal evolution of the vortices? Unfortunately, the use of only two MM precluded the collection of sufficient temporal data to investigate these questions further.

Eddy #4 and #5, 2215 UTC (Fig. 5). Figure 5 reveals two eddies spaced ~3 km apart, each with a similar degree of occlusion, but displaying a noticeable size difference. The vortex to the north was ~4 km in diameter, while the southern vortex spanned ~2 km. Forward motion was the same in both circulations at ~6 m s^{-1}. Note the large dewpoint differential of 6ºC over 500 m collocated with the vortices, while nearly uniform horizontal shear was exhibited across the boundary both ahead of, and behind, the vortices.

3. DISCUSSION

Related to the coherent flow structures and thermodynamic gradients, several questions pertaining to convective initiation are raised by both the MM data and visual observations along the DCVZ. On 16 July, MM operators observed small, spatially random cumulus clouds (CU) with cloud bases estimated to be ~3 km above ground level (AGL) along the convergence line. Narrow towering CU developed shortly thereafter. With time, however, the towering CU began to erode, suggesting the lateral entrainment of lower relative humidity air into the CU and/or the clear plume below the cloud in the boundary layer.

The location of the cloud line overhead was visually determined to be approximately 1 km to the east of the surface wind shift and indicated that weak vertical shear was causing the convergence zone, or the moist plumes rising at the convergence zone to tilt eastward. This observation is in contrast to Wilczak and Christian (1990), who noted that the vertical components of the convergence zone tilted downwind (westward) of the ambient surface flow. Additionally, the appearance of spatially random CU above and immediately within the region 1 km east of the surface boundary, with bases estimated to be as high as 3 km AGL, suggests that the DCVZ was a deep, nearly vertically oriented boundary.

The presence of vortices embedded in the DCVZ has inspired some thought on their contributions to convective initiation. DCVZ vortices may, in theory, protect an air parcel as it ascends by inhibiting the mixing (Andre and Lesieur 1977; Levich and Tsiomber 1983) of drier air and intensifying upward ascent rate. This in turn allows the parcel to reach the LCL and perhaps LFC more readily, thereby promoting the initiation of deep moist convection that might otherwise not have developed.

In their investigation, Roberts and Wilson (1995) documented 4-5 km wavelengths for the eddies sampled. For the eddies described here it was not possible to determine a single dominant wavelength due to the wide variation in the sampled vortex spacing, and, in part, from the limited spatial sampling provided by only two MM.

It should be noted that a number of dust devils were observed. These vortices always rotated cyclonically, and were coincident with the surface shear line. One vortex observed was so intense it would certainly have qualified as a "tornado," had there been a cloud overhead. This vortex was actually embedded in a 100-m scale inflection in the surface wind and a relatively minor wave feature in sampled dewpoint values (intense gradients persisted). Such placement argues against the idea that the intense vortex resulted from the contraction of a larger eddy. Presumably a larger eddy would have more effectively mixed the airmasses horizontally, partially annihilating the dewpoint contrast.

The sampled moisture gradients were strongest in proximity to an eddy. These observations are in contrast to MM findings along the Great Plains dryline (see Pietrycha and Rasmussen 2000, these proceedings). Under the assumption that the eddies are shear related, the vortices exist to mix airmasses and the largest gradients should occur prior to the onset of vortices.

Lastly, the DCVZ remained nearly stationary during the MM intercepts. This lack of boundary movement, as well as the erectness of the boundary, was consistent with little measurable differences in θ_v throughout its width. The θ_v differential was on the order of 1 K 3 km^{-1} across the boundary.

4. CONCLUSIONS

On 16 July 1998, the DCVZ represented a region of generally large convergence containing numerous cyclonic eddies. The eddies varied in size between 500 m–4 km and exhibited assorted degrees of surface occlusion. Vertical vorticity associated with the eddies was found to be on the order of 10^{-2} s^{-1}. Examination of the initiation and maintenance of the observed vortices along the DCVZ is beyond the scope of this paper.

However, their genesis and lifecycle present questions requiring further investigation.

Strong moisture gradients existed across the boundary, the largest of which were always collocated with a vortex. The largest dewpoint differentials observed were 6°C across 500 m. Additionally, a weak density variance in θ_v differentials, on the order of 1 K over 3 km, was documented across the boundary. The data, along with the appearance of CU directly along and immediately east of the boundary, and the stationary nature of the boundary, indicate the DCVZ was nearly vertically oriented.

Visual observations of spatially isolated cumulus suggest that an undefined mechanism(s) was protecting ascending air parcels along the boundary and aiding their ascent. The eddies may contribute to the convective initiation process by protecting the ascending parcels from dilution as they ascend and enhancing upward vertical velocities.

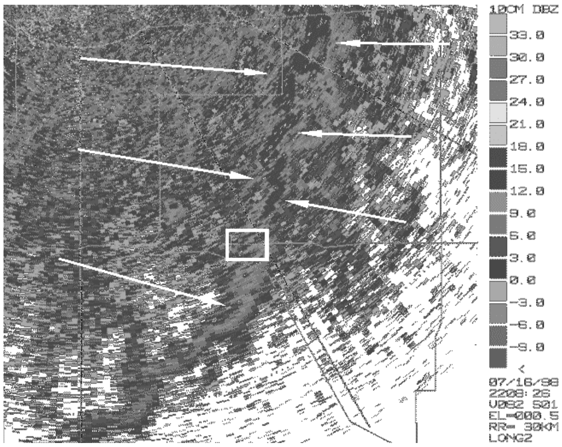

Figure 1. Image of reflectivity data recorded by the CSU-CHILL radar at 2208 UTC 16 July 1998. The Denver Convergence-Vorticity Zone is seen as a NNE-SSW band of enhanced reflectivities. White arrows denote the boundary location; white rectangle mobile mesonet transect locations. Winds to the east of the zone were generally from the southeast; west of the zone, winds were generally lighter and from the northwest.

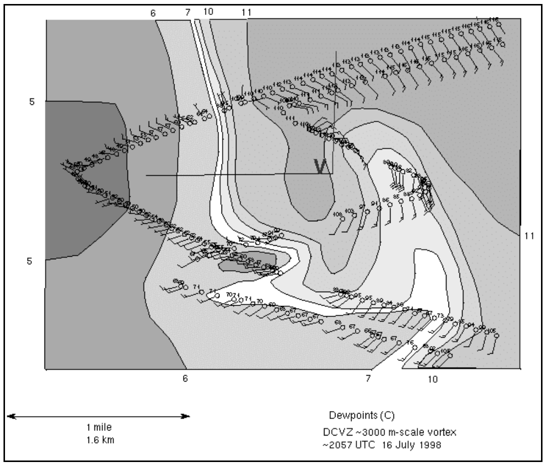

Figure 2. Subjective analysis of mobile mesonet dewpoint temperature (tenths °C) observations across the DCVZ at 2057 UTC on 16 July 1998. Observations are 18-sec averages (3 observations) plotted every 6 sec using time-to-space conversion with a motion vector from 185 at 6.0 m s^{-1}. Isodrosotherms shaded every 1°C. Winds in knots with one full barb, and one half barb equal to 10, and 5 knots, respectively.

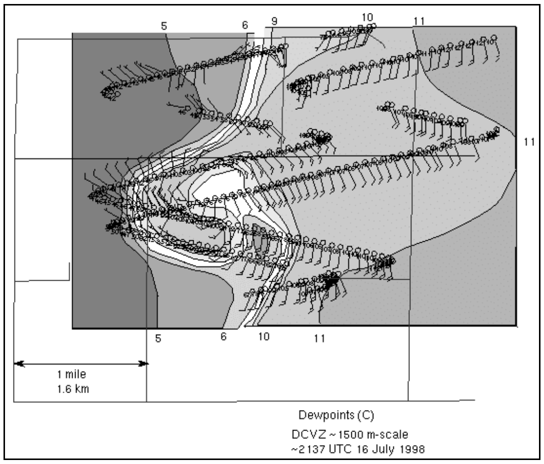

Figure 3. As in Fig. 2 except for 2137 UTC 16 July 1998.

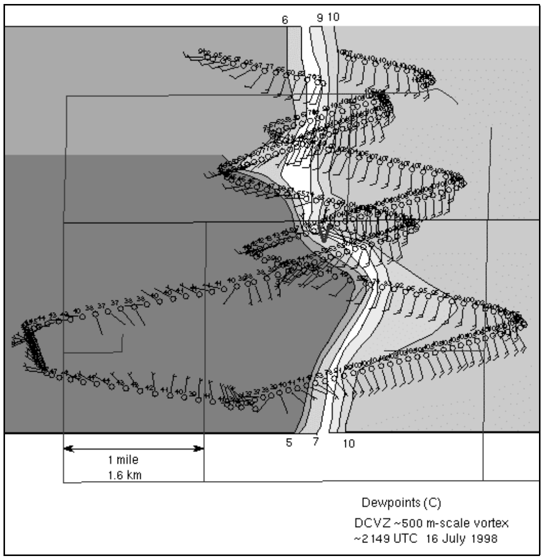

Figure 4. Subjective analysis of mobile mesonet dewpoint temperature as in Fig. 2 except for 2149 UTC 16 July 1998.

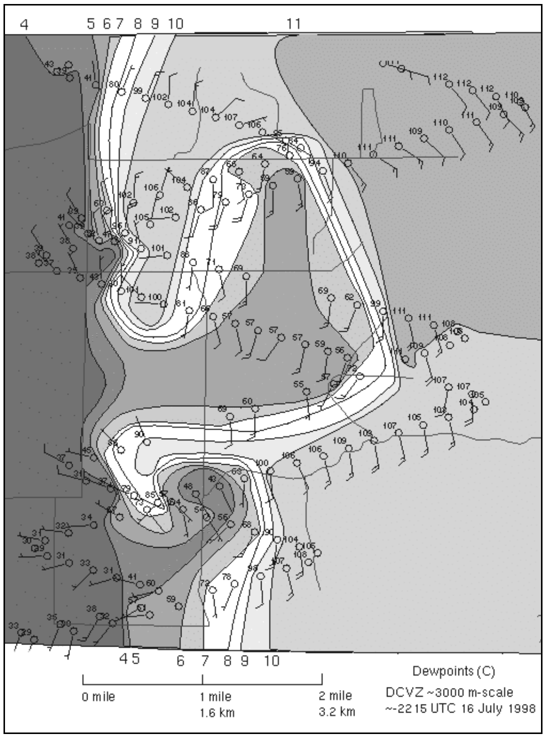

Figure 5. As in Fig. 2 except for 2215 UTC 16 July 1998.

5. ACKNOWLEDGMENTS

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6. REFERENCES

References available upon request.