P7.4 THE 3 MAY 1999 DRYLINES: A CLOSER EXAMINATION

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1. INTRODUCTION

At the time of this writing, several observational and numerical modeling conference papers (e.g., Edwards and Thompson 2000; Smith et al. 2000; Weiss and Stensrud 2000), and one formal publication (Thompson and Edwards 2000, hereafter TE) have documented the evolution of surface features and development of deep moist convection associated with the 3 May 1999 tornadic outbreak. TE presented an analysis of two meridional drylines (DLs) forming during the afternoon hours of 3 May 1999, portions of which extended across west central Oklahoma and far northwestern Texas (also see Fig. 3d TE). DL analysis by Foster et al. (2000) indicated portions of the western DL remained over the western Texas panhandle throughout the day. The occurrence of rain over the Texas panhandle on 2 May 1999 created high soil moisture content and may have led to a cooler, shallower planetary boundary layer. Foster et al. suggested that the lack of vertical mixing prevented the western DL from advancing eastward off the Caprock during the afternoon of 3 May.

The purpose of this paper is to reexamine the evolution of the two DLs. The existence of the two DLs is not in question, nor is the argument that increased surface water vapor flux may be attributed to large soil moisture levels. Indeed, the effects of evaporative moisture on each DL must remain in question. The placement and evolution, however, of the two DLs as presented by TE is refined. Furthermore, the results documented herein demonstrate that the evolution of the western DL first developed in portions of western Oklahoma and the Texas panhandle as it retrograded onto the Texas Caprock.

2. DATA AND RESULTS

Descriptions of the synoptic environment and early evolution of surface features are beyond the scope of this paper. The reader is referred to TE for a detailed account of these conditions. Additionally, the paper follows the naming convention of deep moist convection as used by TE (e.g., "storm B"). The DL analysis depicted herein is based on the location of the largest surface moisture differentials.

During the late morning hours of 3 May 1999, a nearly meridional primary DL extended from central Kansas, across western Oklahoma, to the Big Bend region of Texas. In southwesterly winds behind the primary DL, dewpoint values ranged from the low to mid 30˚s F across the Texas and Oklahoma panhandles, to the mid-40˚s F across West Texas. Surface dewpoints over West Texas and the Texas/Oklahoma panhandles rose slowly and uniformly throughout the afternoon, despite the region's position behind the primary DL. As discussed by Foster et al. (2000), the increasing afternoon moisture levels may be attributed to surface water vapor flux of large soil moisture. East of the primary DL, western and central Oklahoma dewpoints ranged from the low to mid 60˚s F within southwesterly-to-southeasterly winds.

Hourly surface pressure tendencies indicated a persistent, broad pressure fall center ($\geq$1 mb h^{-1}) exceeding that typically associated with diurnal processes, during the afternoon hours. The fall center migrated from extreme southeastern Colorado to northeastern and east central New Mexico. Presumably, the pressure fall center was partly in response to an approaching middle- and upper-level short-wave trough. Additionally, a secondary pressure fall center developed and persisted through the afternoon and early evening hours over southwestern Oklahoma. The portion of the primary DL situated over southwestern Oklahoma remained immediately west of the fall center.

Isodrosotherm analysis at 2000 UTC revealed an apparent "fracture" in the horizontal moisture gradient associated with the DL (Fig. 1a). A second DL began to develop rapidly west of the primary DL, as a relatively narrow tongue of moisture retreated westward into extreme northwest Oklahoma, and approached the Caprock escarpment. The boundary's westward retrogression apparently occurred in response to surface pressure falls over northeast New Mexico and southeast Colorado. Concurrently, Oklahoma mesonet (Brock et al. 1995) observations indicated the primary DL remained nearly stationary across west central Oklahoma. This boundary was associated with weak surface convergence and a relatively small horizontal moisture gradient (4°F over 24 km). Furthermore, time series utilizing 15-min Oklahoma mesonet data indicated the development of a DL wave that moved north along the primary DL during the afternoon (Fig. 1a-d). The evolution of the wave and its possible implications toward the initiation of deep moist convection are beyond the scope of this paper.

Of note, an accurate depiction and placement of where the western DL terminated into the primary DL is not possible, due to the scarcity of spatial and temporal surface observations available in northwest Texas, and southern Kansas. Additionally, with the

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exception of the southern portion the primary DL in Texas, a persistent thick cirrus canopy prevented detection and tracking, via *GOES*-8 visible imagery, of any small cumulus clouds that may have been present along the DLs. The detection of cumulus would have aided the placement of the boundaries in both time and space.

At 2100 UTC, moisture differentials uniformly increased along the western DL as the DL retreated to the Caprock (Fig. 1b). Amarillo reported a 50°F dewpoint with 180° winds, increased by 4°F and backed 30°, respectively, from observations at 1900 UTC (Fig. 2). A similar wind and moisture trend was measured at Borger in the forthcoming hour as that portion of the DL moved northward on the Caprock. It is unclear how the moisture advected westward (in association with New Mexico pressure falls) without an easterly component to the surface winds. It is plausible that the moisture advected over the region from the south-southeast instead of the east. Based on *GOES*-8 visible imagery, the cirrus plume was thickest across the southeast Texas panhandle, and it may have been horizontal advection of cooler 'less mixed' air beneath the cirrus, which had accumulated more near surface moisture through evapotranspiration that was not offset by deep mixing.

Mesonet observations indicated the primary DL across north central Oklahoma remained quasi-stationary with no appreciable change in the horizontal moisture gradient or surface convergence. The horizontal moisture gradient across the primary DL over southwestern Oklahoma became increasingly large (6°F over 8 km) as a subtle DL bulge developed. Of note, at 2121 UTC, the time storm B initiated (TE), the winds at Childress veered 50° from the 2100 UTC observation and gusted to 25 kt (Fig. 3). These surface observations, in conjunction with an isallobaric analysis, suggest the eastward bulge of the primary DL developed in response to an increased isallobaric flow, associated with the surface pressure fall center located immediately east of the primary DL, over southwestern Oklahoma.

Between 2200 and 2300 UTC (Fig. 1c-d) the northern portion of the western DL continued to propagate slowly northwestward along the Caprock, while the horizontal moisture gradient became large. Moisture differentials weakened along the southern portion of the western DL as it began to mix more east into western Oklahoma. With a slight retrogression westward over north central Oklahoma, the bulge along the primary DL became less apparent as moisture differentials and surface convergence increased along its extent across Oklahoma. By 0000 UTC 4 May (not shown), the western DL had rapidly propagated east and merged with the primary DL over west central Oklahoma.

3. CONCLUSIONS

Two DLs developed during the afternoon of 3 May 1999. The primary DL extended across western Oklahoma while remaining nearly stationary throughout the day. Prior to the increase in the horizontal moisture differentials across the primary DL, a subtle eastward DL bulge developed over extreme southwestern Oklahoma. The westerly wind surge associated with the bulge resulted from isallobaric flow associated with a persistent surface pressure fall center located immediately ahead of the primary DL over southwestern Oklahoma. Additionally, the surge and subsequent DL bulge transpired 15-30 min prior to the initiation of storm B. The relationship, if any, of the juxtaposition of the DL bulge and a cirrus canopy gap (TE) over the region to the initiation of storm B is unclear and is suggested as a subject for future investigation. Between 2000 and 2300 UTC a DL wave moved north along the primary DL. The development of the wave and its possible association with convective initiation is currently under investigation.

The western DL developed rapidly as surface moisture migrated westward out of portions of Oklahoma and the Texas panhandle, over the Texas Caprock, and across the northwestern corner of Oklahoma. The development of the western DL is believed to have been in response to surface pressure falls over southeastern Colorado and eastern New Mexico. The horizontal moisture gradient across the western DL became large during the evolution of its retreat. By late afternoon, the western DL rapidly propagated eastward and eventually merged with the primary DL.

One question is raised by this investigation: By what mechanisms was the primary DL maintained across west central Oklahoma throughout the afternoon hours, even as the western DL formed and evolved? A plausible explanation may reside in local effects on vertical mixing influenced by the local vegetation, land use, and the consequent soil moisture variables. Numerical simulation studies have suggested that dryline moisture gradients are highly sensitive to horizontal soil moisture and vegetation type (Lanicci et al. 1987; Ziegler et al. 1995; Shaw et al. 1997; Grasso 2000); constant horizontal soil moisture and non-varying vegetation type lead to small moisture gradients across a DL. Additionally, Weaver and Avissar (2001) have documented the occurrence of localized mesoscale circulations within the planetary boundary layer induced by landscape heterogeneity. The influence of the above factors on vertical mixing and subsequent maintenance of the primary DL in Oklahoma remains unclear without quantifiable soil moisture data specific to the day and area. Nonetheless, a re-examination of conventional theories regarding DL development and maintenance may be worthwhile.

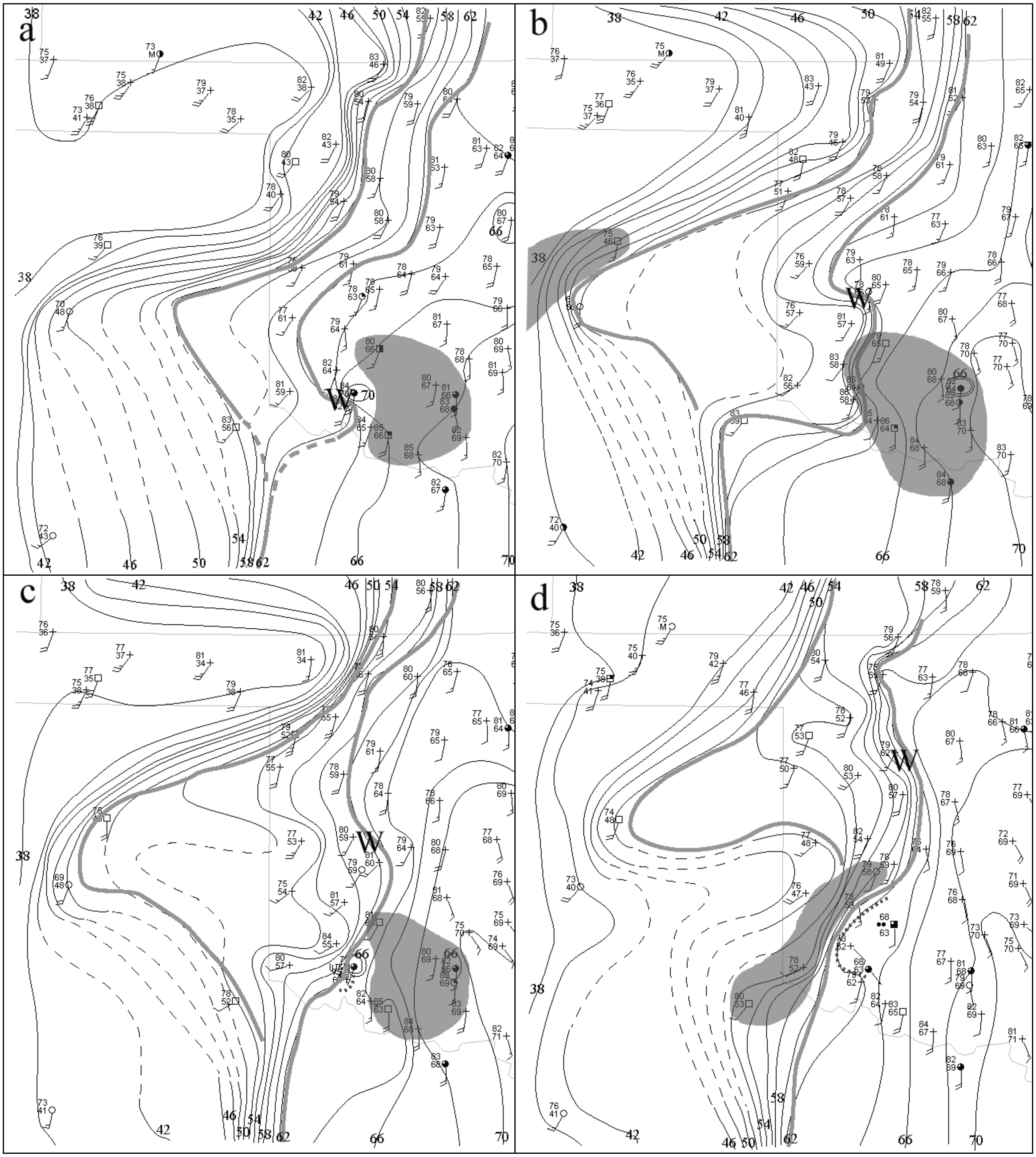

Fig. 1. Hourly surface observations with dryline (thick line), dewpoint analysis (thin line), and outflow boundaries (dotted line). Isodrosotherms contoured every 2°F (≥38°F) valid (a) 2000, (b) 2100, (c) 2200, and (d) 2300 UTC 3 May 1999. Station model is standard. Dashed lines depict regions of analysis uncertainty due to low observation density. In (a) and (b) shading denotes surface pressure falls ≥1.0 mb h^{-1}; ≥1.5 mb h^{-1} in (c) and (d). The bold W indicates the placement of the dryline wave.

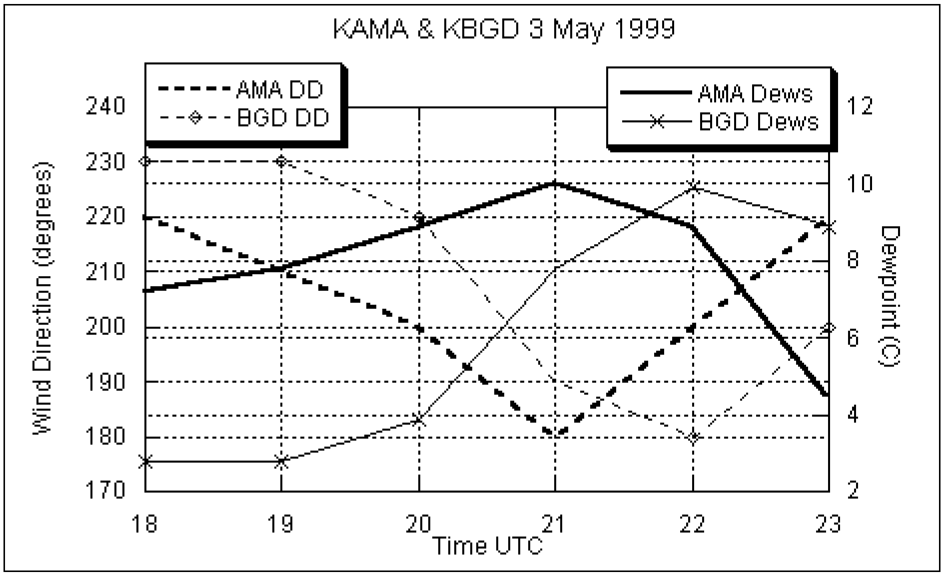

Fig. 2. Time series of wind direction and dewpoints (°F) for Amarillo and Borger, TX, between 1800-2300 UTC 3 May 1999.

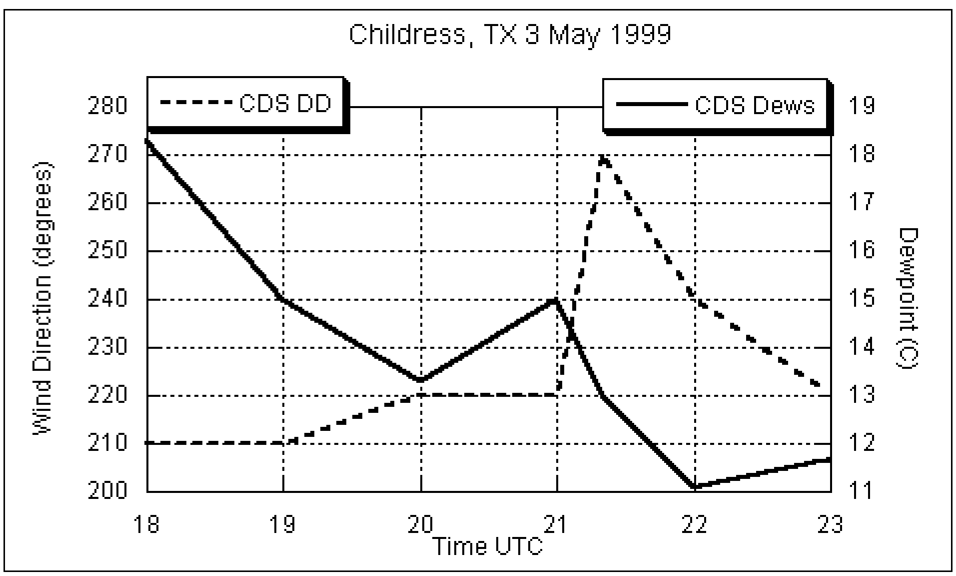

Fig. 3. As in Fig. 2 but for Childress, TX.

4. ACKNOWLEDGMENTS

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5. REFERENCES

Available upon request.