2.6 SYNOPTIC AND MESOSCALE INFLUENCES ON WEST TEXAS DRYLINE DEVELOPMENT AND ASSOCIATED CONVECTION

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1. INTRODUCTION

Previous research has identified a multitude of forcing mechanisms for drylines, which span a spectrum of spatial scales. The influence of vertical mixing, for example, and the associated heterogeneities thereof owing to terrain slope and gradients in land use and vegetation, can span across the full width of the mesoscale. Mesoscale influences are a subject of ongoing investigation (e.g., IHOP_2002 (Weckwerth et al. 2004); the Simultaneous Observation of the Near-Dryline Environment (SONDE) experiment at Texas Tech University in 2005 and 2006 (Weiss 2005)).

Considering the colloquially-recognized correlation between dryline intensity and the background synoptic pattern, one should expect elements of this synoptic pattern to be significant in the prediction of drylines (e.g., the Rocky Mountain lee trough (McCarthy and Koch 1982)) and associated convection initiation.

The purpose of this study is to establish the significance of synoptic parameters in the development and intensity of drylines in west Texas (further detailed in Schultz et al. 2006), and statistically test the forcing of these parameters on the propensity and severity of associated convective development.

2. DRYLINE CASE SELECTION

Cases for this study were selected from 182 possible spring days (April-June) spanning 2004 and 2005. Data from the West Texas Mesonet (Schroeder et al. 2005), a 48 station array recording standard meteorological variables across primarily the southern Texas panhandle, were used to select these cases. In particular, the set of criteria to be satisfied for a dryline case included:

- An eastward-directed dewpoint gradient at 1800 LT,
- The above dewpoint gradient was not attributed in whole or in part to a frontal boundary,
- The dewpoint gradient was not significantly influenced by convective outflow,
- The dewpoint difference between WTM stations Morton (MORT) and Paducah (PADU) increased between 0700 and 1800 LT,
- The dewpoint difference between MORT and PADU exceeded 1 deg C, the threshold value corresponding to a constant water vapor mixing ratio for the altitude of each station,
- A deceleration in eastward propagation / acceleration in westward propagation was noted after the diurnal cessation of sensible heating (after 1800 LT), and
- The majority of the entire dewpoint gradient resided within the WTM domain.

One noticeable omission from the selection procedure was the imposition of a minimum horizontal dewpoint gradient threshold (beyond the adjustment made for the elevation change across the WTM domain). Indeed, when investigating potential cases, it was obvious that there existed a continuous spectrum of dryline events in west Texas, such that the declaration of an arbitrary threshold for dewpoint gradient would unnecessarily eliminate valid cases. Many of these weak cases may not be readily recognized as dryline events, especially without the aid of the WTM. However, all selected cases displayed common traits of drylines (e.g., a diurnally-driven intensification of an eastward-directed specific humidity gradient), and were therefore deemed dryline cases. Also of note is that no kinematic constraints (e.g., convergence) were imposed. Rather, cases were selected according to the presence and behavior of an eastward-directed moisture gradient.

The selection criteria yielded 64 cases for the two spring seasons. The remaining spring days were classified as “no-boundary” if no dryline

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or frontal boundary was present in the vicinity of the WTM domain. Further explanation of the methodology will follow in subsequent sections.

3. SYNOPTIC INFLUENCES ON DRYLINES

The 64 cases were ranked according to four calculated variables:

- Difference in 1800 LT dewpoint temperature between MORT and PADU (ΔT_d; "dryline intensity"),
- The maximum difference in 1800 LT dewpoint temperature between any two WTM stations along an east-west line between MORT and PADU ($\Delta T_{d,\,max}$),
- The difference in 1800 LT zonal wind velocity between MORT and PADU (Δu; "dryline confluence"), and
- The difference in ΔT_d between 0700 and 1800 LT ($\Delta(\Delta T_d)$).

Owing to the high correlation between ΔT_d, $\Delta T_{d,max}$, and $\Delta(\Delta T_d)$, only ΔT_d and Δu will be considered in this study.

A Pearson correlation coefficient of R=0.73 was calculated for the relationship between ΔT_d and Δu (FIG. 1). In other words, cases featuring stronger WTM-scale confluence also resulted in stronger drylines. Occasional large departures from the relationship were noted, though, where other forcing factors likely played a prominent role.

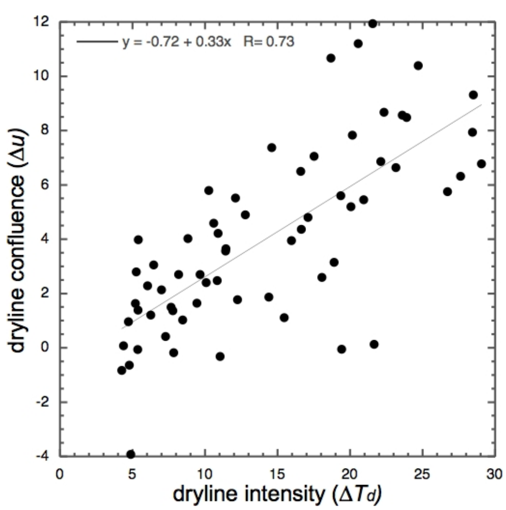

FIG. 1 – Scatter plot of dryline intensity (ΔT_d) versus dryline confluence (Δu) from 64 dryline days in 2004 and 2005. The gray line represents linear regression of data. (from Schultz et al. 2006)

Dryline cases were split into quartiles of 16 events based upon ΔT_d. The top quarter of cases were considered "strong" drylines, while the bottom quarter of cases were termed "weak" drylines. The resultant cases were then composited using the NCEP-NCAR Reanalysis dataset (Kalnay et al. 1996) available via the National Oceanic and Atmospheric Administration–Cooperative Institute for Research in Environmental Sciences (NOAA–CIRES) Climate Diagnostics Center Web site (http://www.cdc.noaa.gov).

Based upon the strong and weak composites, striking differences in the synoptic pattern are apparent (FIG. 2). For weak drylines, anti-cyclonic flow is evident upstream of the WTM domain at 250 hPa and 500 hPa, whereas strong drylines exhibit a trough over the four-corners region, the surface reflection of which is a 1004 hPa surface low centered near the Texas/New Mexico border. The kinematic response to this surface low, particularly to the east of the dryline where boundary-layer winds have not mixed with the free troposphere, is consistent with the trend for stronger confluence in strong dryline cases (FIG. 1)

Comparing weak dryline cases and no-boundary cases, it is clear in the sea level pressure field (FIG. 3) that the Rocky Mountain lee trough is more prominent in the former case than the latter. We pose this information as evidence that pressure falls in the lee of Rocky Mountains are important for the development of drylines, perhaps by forcing confluence of the flow along the high Plains. Confluent flow will force frontogenesis, and the resultant solenoidal frontogenetical circulation (given an adequate horizontal density gradient) can supplement other mesoscale frontogenetical features related to the surface sensible heat flux and the heterogeneities thereof.

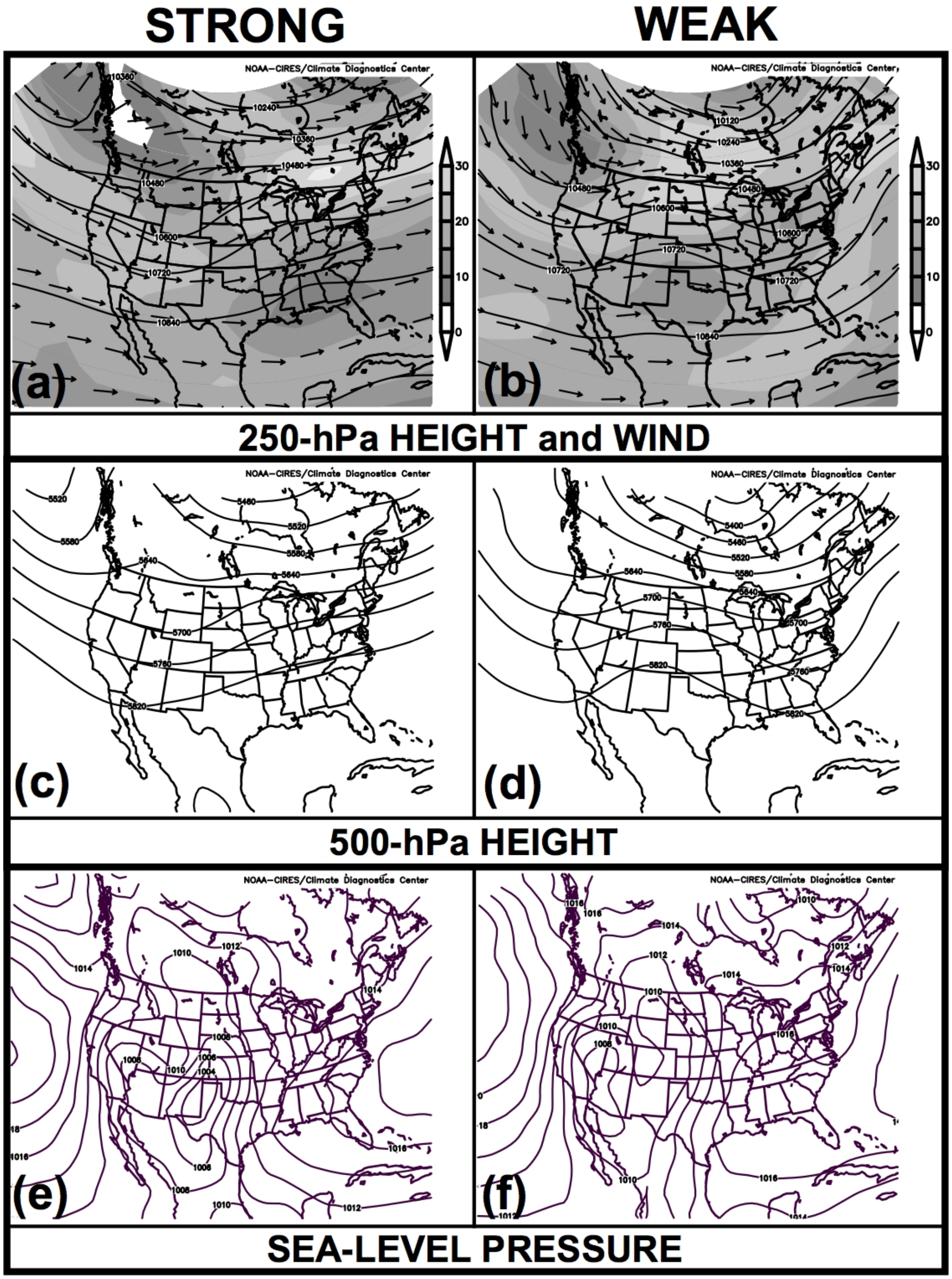

FIG. 2 – STRONG (left column) vs WEAK (right column) dryline composites: (a) and (b) 250-hPa geopotential height (solid lines every 120 m), wind speed (m s^{-1}, shaded according to scale), and wind direction (vectors); (c) and (d) 500-hPa geopotential height (solid lines every 60 m); (e) and (f) sea level pressure (solid lines every 2 hPa). (from Schultz et al. 2006)

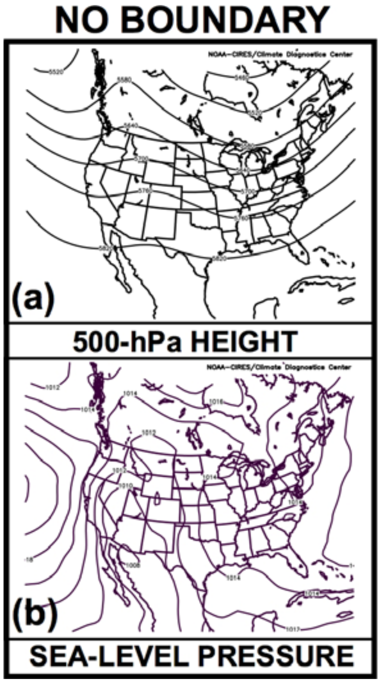

FIG. 3 – Composite for cases with no dryline present: (a) 500 hPa geopotential height (solid lines every 60 m), and (b) sea level pressure (solid lines every 2 hPa). (from Schultz et al. 2006)

4. SYNOPTIC INFLUENCES ON DRYLINE CONVECTION

Satellite, WSR-88D, and WTM data were analyzed for the 64 dryline cases to classify each event according to the existence and intensity of resulting convection. The classification scheme included:

- No moist convection,
- At least one example of shallow moist convection,
- At least one cumulonimbus with precipitation in the WTM domain / no severe weather reports in WTM domain,
- At least one cumulonimbus with precipitation in the WTM domain / hail and damaging wind severe weather reports, only, in the WTM domain, and
- As in the previous designation, except with at least one tornado report.

Logistic regression (Ryan 1997) was employed to ascertain the significance of potential predictors. Logistic regression fits potential predictors to a logit curve (FIG. 4), the probable value of which clusters to the limits “0” and “1”. Therefore, logistic regression is a powerful tool

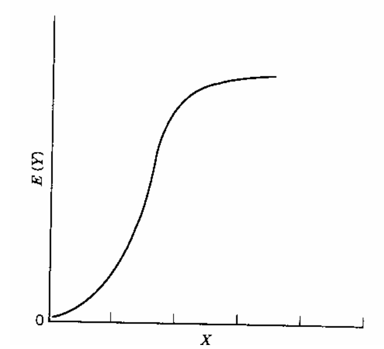

FIG. 4 – A trace of the logit function (from Ryan 1997)

and an appropriate model for binomial (“switch”) response variables.

For each case listed below, an intercept-only model (IOM) was created first to fit the chosen response variable. From there, a stepwise selection procedure iteratively built significant regressors upon the IOM.

The potential predictors included for this study (Table 1) were collected from either the WTM or two gridpoints (FIG. 5) from the NCEP-NCAR Reanalysis dataset (as in section 3). Gridpoint #3416 (hereafter, “W”) was located along the southern periphery of the WTM domain, while gridpoint #3417 (hereafter, “E”) was east of the WTM domain. Considering the WTM-domain constraint placed on dryline cases in this study, position “E” was clearly east of all drylines, while position “W” could have been either west or east of the drylines. As a consequence of this uncertainty, q_{850} was removed as a predictor for position “W”.

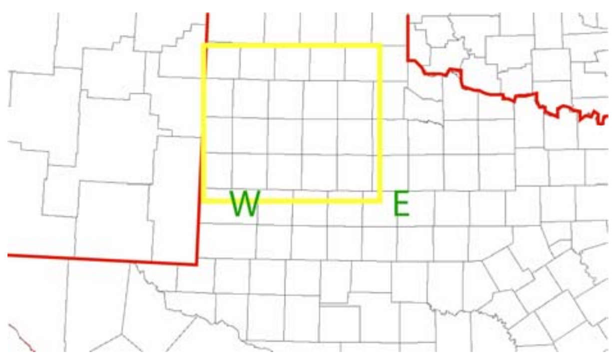

FIG. 5 – The approximate domain for the study. Red lines indicates the New Mexico, Texas, and Oklahoma state borders, the green letters represent the location of gridpoints “W” and “E” from the reanalysis data, and the yellow box indicates the boundaries of the WTM stations used in this study.

Variable	Description
$\Delta \mathrm{T}_{\mathrm{d}}$	Dewpoint difference between MORT and PADU at 1800 LT
$\Delta \mathrm{T}_{\mathrm{d,max}}$	Maximum dewpoint difference between adjacent east-west stations at 1800 LT
$\Delta \mathrm{u}$	Difference in zonal wind component between MORT and PADU at 1800 LT
$\mathrm{q}_{850,700,500}$	Specific humidity at level XXX hPa at 0000 UTC (q_{850} not used for location "W")
$\mathrm{T}_{850,700,500}$	Temperature at level XXX hPa at 0000 UTC
$\mathrm{U}_{700,500}$	Zonal wind component at level XXX hPa at 0000 UTC
$\mathrm{T}_{850\text{-}500}$	Temperature lapse rate from 850 to 500 hPa at 0000 UTC
$\mathrm{T}_{700\text{-}500}$	Temperature lapse rate from 700 to 500 hPa at 0000 UTC
$\mathrm{T}_{850\text{-}700}$	Temperature lapse rate from 850 to 700 hPa at 0000 UTC

TABLE 1 – The potential predictors used in this study.

Twelve models were developed in total, six models for each gridpoint (bulleted below). The response variable for each model was assigned a value of "1" as follows:

- Cu – for all dryline cases, any moist convection along the dryline;
- Cb – for all dryline cases, any cumulonimbus (Cb) development along the dryline;
- Severe – for all dryline cases, any Cb development with associated non-tornadic severe weather reports in the WTM domain;
- Tornado – for all dryline cases, any Cb development with at least one tornado report in the WTM domain;
- Severe | Cb – for all dryline Cb cases, any severe weather reports in the WTM domain; and
- Tornado | Cb – for all dryline Cb cases, any tornado reports in the WTM domain.

The preliminary results from the constructed models (Table 2) highlight a number of interesting outcomes. As expected, lower-tropospheric specific humidity and mid-tropospheric temperature primarily force the signal in moist convection at both "W" and "E".

For the development of dryline cumulonimbus clouds, q_{700} proves to be more significant in prediction that q_{850} to the east of the dryline, signaling perhaps the detrimental effects of entrainment/detrainment on typically narrow dryline thermals that are decelerating through the typical region of convective inhibition (CIN). The 850 hPa-500 hPa lapse rate has an expected positive correlation with Cb development.

Model	Location	Predictors (in order of selection)
Cu	W	q_{700}, $\Delta\mathrm{T}_{\mathrm{d}}$, T_{500}
Cb	W	T_{850}–T_{500}, q_{700}, $\Delta\mathrm{T}_{\mathrm{d}}$, T_{700}
Severe	W	$\Delta\mathrm{T}_{\mathrm{d}}$, q_{700}, T_{500}
Tornado	W	$\Delta\mathrm{T}_{\mathrm{d,max}}$, U_{500}, T_{850}
Severe|Cb	W	$\Delta\mathrm{T}_{\mathrm{d}}$
Tornado|Cb	W	U_{500}, T_{850}, $\Delta\mathrm{U}$, ΔT_d
Cu	E	q_{700}, T_{500}, q_{850}
Cb	E	q_{700}, T_{850}–T_{500}
Severe	E	$\Delta\mathrm{T}_{\mathrm{d}}$, T_{700}–T_{500}, q_{700}
Tornado	E	$\Delta\mathrm{T}_{\mathrm{d,max}}$, U_{500}, T_{850}–T_{500}
Severe|Cb	E	T_{700}–T_{500}, T_{850}–T_{500}
Tornado|Cb	E	U_{500}, T_{700}, $\Delta\mathrm{U}$, ΔT_d

TABLE 2 – Significant predictors for each regression model at gridpoints "W" and "E". Predictors are defined in Table 1. Predictors in italics have a negative coefficient in the regression model.

Interestingly, metrics of the dryline strength ($\Delta\mathrm{T}_{\mathrm{d}}$ and $\Delta\mathrm{T}_{\mathrm{d,max}}$) appear as significant predictors of the *severity* of convection at position "W", which is close to the region of convection initiation in most cases. Even when the model is posed with the condition of a Cb met, these metrics appear important.

The prominence of U_{500} in the tornado models at position "W" and "E" is consistent with the well-known importance of lower-middle tropospheric wind shear for the development of supercell thunderstorms. The inclusion of $\Delta\mathrm{u}$ likely represents the effect of easterly-component surface winds on the same wind shear vector.

5. SUMMARY AND DISCUSSION

West Texas Mesonet data from the springs of 2004 and 2005 were used to create a database of dryline cases in the southern Texas Panhandle. The inspection of all cases made quite clear the fact that a continuous spectrum of dryline intensity exists from case-to-case, and the imposition of an arbitrary horizontal dewpoint gradient threshold does remove meaningful low-end cases.

The first part of the study investigates synoptic controls on dryline intensity. It is found that the background synoptic pattern varies considerably for high-end and low-end dryline events at all levels of the troposphere. For the stronger dryline cases, upper-tropospheric flow is farther south in latitude, with a trough typically evident over the western United States (many low-end cases actually feature a ridge in this same area). Also, when comparing weak cases to null cases, it is apparent that the Rocky Mountain lee trough is significant for the development of any dryline.

The second part of the study considers the effect of dryline intensity and near-dryline environmental parameters on the development and intensity of moist dryline convection. Specific humidity at 700 hPa was shown to be more correlated to convection initiation than the same quantity at 850 hPa. Metrics of dryline intensity also appear to strongly force convective development.

Much of the work in section 4 is preliminary and will be given further scrutiny.

6. ACKNOWLEDGEMENTS

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