1.5 # A mesoscale analysis of the Lubbock area bow echo of 30 May 2001

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1. INTRODUCTION

It is well known that convective storms possessing a bow-shaped reflectivity signature are quite often associated with severe surface wind gusts. The environment in which bow echoes develop has been studied by means of numerous case studies and numerical modeling (Pryzbylinski, 1995). In particular, a certain subset of bow echoes that achieve a steady-state structure called the derecho, has been the focus of much research due to their ability to produce a long swath of damage (Johns and Hirt, 1987). However, bow echo structures that are more temporal in nature seem to lack documentation in terms of the operational environments that might spawn such features. In particular, what precursors might be found which would signal transition of a convective system to a bow echo structure? Also, should the conditions for steady state structure not be met, what potential does such a system have to produce extremely damaging winds with respect to its more steady counterparts?

Numerical modeling studies have shown a tendency for convective modes to take on bow echo characteristics for moderate to strong shear values and large values of CAPE (Weisman and Klemp, 1982). Steady state structures were simulated for environments characterized by large values of low-level shear and high CAPE. However, the ability for non-steady state structures to produce exceptionally strong winds has not been well documented.

One such system, which did not meet the criteria for a derecho but certainly maintained a bow echo structure over a significant distance, occurred over Lubbock, Texas on May 30, 2001. What made this event unique were the magnitude of the surface winds produced (~ 91 kt), the relatively benign severe weather parameters, and the proximity of the system to the West Texas Mesonet. The production of extremely damaging winds by this system seems to be an enigma, as parameters indicated the potential for large hail and moderately severe winds, but nothing of the magnitude observed.

The current study seeks to investigate the mesoscale environment in which this storm developed to identify mechanisms that may have contributed to the production of such extreme surface winds. Also, questions related to the steadiness of the system and its lack thereof will be examined. Finally, forthcoming model simulations of this event will be discussed.

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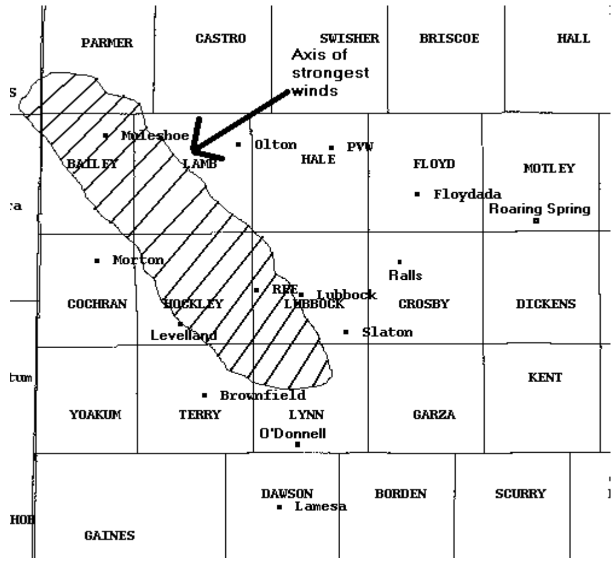

Figure 1. Map of area affected by wind damage. Cities with operational West Texas Mesonet Sites at time of the event denoted on map. Lubbock included for reference.

2. Synoptic/Mesoscale Environment

On May 30th, the environment over the West Texas South Plains was characterized by moist easterly flow in the wake of a surface boundary that had passed through the region the night before. This boundary was associated with a significant mid-level shortwave trough that contributed to a significant severe weather outbreak the previous day throughout the Texas panhandle. The surface boundary had become stationary by midday on May 30th, oriented in a SW-NE manner extending from north of Midland, Texas to northwest of Wichita Falls, Texas. Dewpoints south and east of this boundary were in the upper 60's to lower 70's while north and west of the boundary dewpoints were in the mid to upper 50's. Although the boundary marked a zone of significant confluence, the temperature difference across the boundary was fairly diffuse.

At 1200Z on the 30th, the Texas Panhandle region was located in the confluence region of an exiting shortwave at the 300 mb level. Although significant data was missing, an approaching shortwave trough with attendant diffluence was located over Utah in a northwesterly flow regime. At 500 mb, a 50 kt Wind max was moving through the Red River Valley with winds weakening to 20 kt over the Texas Panhandle region and becoming northwesterly. Only a weak reflection of an approaching shortwave could be seen in the height contours over Utah with a significant low over the northwestern US. Winds remained weak and northwesterly around the 700 mb and 850 mb levels with a northwest to southeast oriented baroclinic zone through the Texas panhandle extending into northeast New Mexico at 850 mb.

As the day progressed wind speeds and direction changed very little throughout the lower and middle troposphere with weak northwesterly flow prevailing at 0000 Z. However, the winds at the 300 mb level increased to 40 kt over northeast New

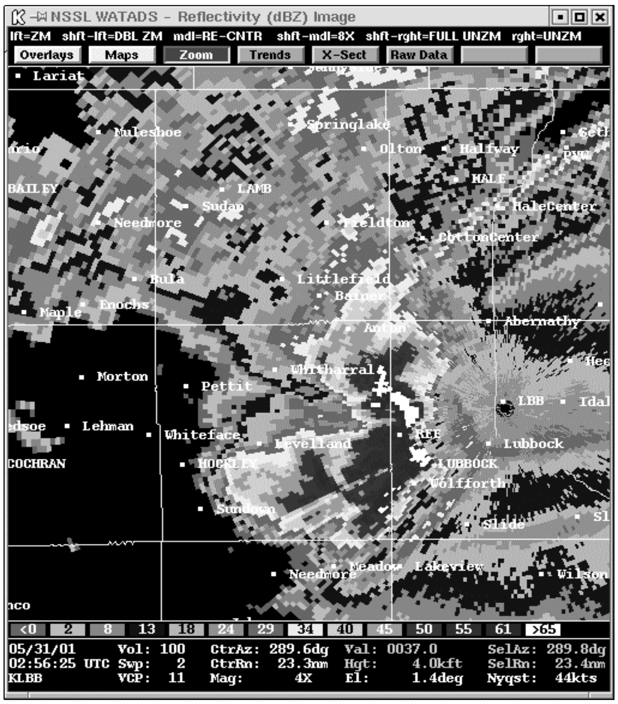

Figure 2. NEXRAD Level II Data from LBB for 0256 UTC, sweep 2. DBZ scale given at bottom of window.

Mexico and the northern Texas Panhandle in association with the approaching exit region of an upper level wind max and attendant trough. Interestingly, the surface flow remained fairly constant throughout the day with a very slight increase in wind speeds into the 10-20 kt range. Accordingly, deep layer shear values increased slightly through the day, particularly in the north Texas panhandle, while low-level shear values remained nearly the same.

Around 1730 UTC to 1750 UTC thunderstorms began to develop over the higher terrain in north central New Mexico in a region of moist upslope flow. This activity remained anchored to the higher terrain for some time, with a well-developed anvil shield present over much of northeastern New Mexico at 2100 UTC. At this time, other thunderstorm activity was beginning to develop along the surface boundary located over northwest Texas near Midland northeastward. Throughout the period, easterly flow between a developing thermal low northeast of El Paso and an intensifying surface high over southeast Colorado was being maintained with moist air being advected up the higher terrain over northeastern New Mexico. It will be seen that the orientation of the low level flow has significant implications for the strength of the storm-relative flow on the developing convective complex moving out of northeast New Mexico.

The 0000 UTC sounding at Amarillo displays a fairly unstable environment with marginal shear values representative of the preconvective environment in the Texas panhandle. With a CAPE value of 1978 j/kg and a bulk Richardson number of 42 it is apparent that supercellular convection would be a distinct possibility should thunderstorms develop. Furthering this argument, the Tucumcari, New Mexico profiler reveals significant turning of the low level winds with height with marginal speed shear. As the exit region of the upper level jet max over Utah approached it is likely that the deep layer shear was even greater near the region of initiation over north central New Mexico, with decreasing shear values as one moves southeastward.

3. Level II Data

By 2200 UTC, two discrete supercells were beginning to move out of eastern New Mexico approaching the Texas panhandle. The northern storm displayed >65 dbZ until 2348 UTC at which time it began to weaken while the southern supercell maintained and increased in intensity with a >65 dbZ appearing at 0059 UTC east of Clovis, New Mexico on the Texas/New Mexico border. At this time, a general area of 25-30 dbZ reflectivity was beginning to expand north and west of Amarillo, Texas with some isolated 34 dbZ values.

By 0104 UTC a well-developed fine line is seen to be surging ahead of the right rear flank on the southern supercell. Storm-relative velocities were folded at this distance so the identification of a mesocyclone based upon velocity data could not be accomplished. However, the reflectivity data revealed some interesting characteristics typical of supercell thunderstorms such as an inflow notch with a tight reflectivity gradient on the right front flank and a BWER within this same region of the storm. The distinct fine line on the right rear flank of the storm suggests this may be an indication of a well-developed RFD as the storm is becoming outflow dominant.

Meanwhile, activity continued to develop along the boundary over the south plains near Midland with a new fine line moving northwestward away from new development, north of the initial convection along the boundary. This feature continued to progress northwestward, likely being helped by the background easterly flow, with it approaching the southeast corner of Lubbock County and becoming somewhat diffuse by 0214 UTC.

Winds of >50 kt began to be reported at this time near Muleshoe over Bailey County. At 0154 UTC the reflectivity began to take on a more line segment appearance with the northern edge of the reflectivity indicating a developing circulation. A linear band of reflectivity over 65 dbZ persisted at the leading edge of the system at this time. Storm relative velocity data revealed an enhanced area of inbound winds beginning at 0124 UTC and continuing with increasing area as the storm progressed towards Lubbock County.

The existence of such winds at nearly 45 miles from the radar site indicates that an elevated rear inflow jet may be developing at this time. Cross sections and temporal persistence of this feature verify such a conclusion. As the system continued to take on more of a bow shaped appearance, storm relative velocity data at 0219 UTC revealed the existence of a well defined mesocyclone on the northern fringe of the developing bow, commonly referred to as the bookend vortices. Interestingly, a vortex of the opposite sense was never detected on the southern edge of the system. Although the system had maintained itself for quite some time, it is unlikely that Coriolis effects were beginning to favor the northern circulation over a southern member.

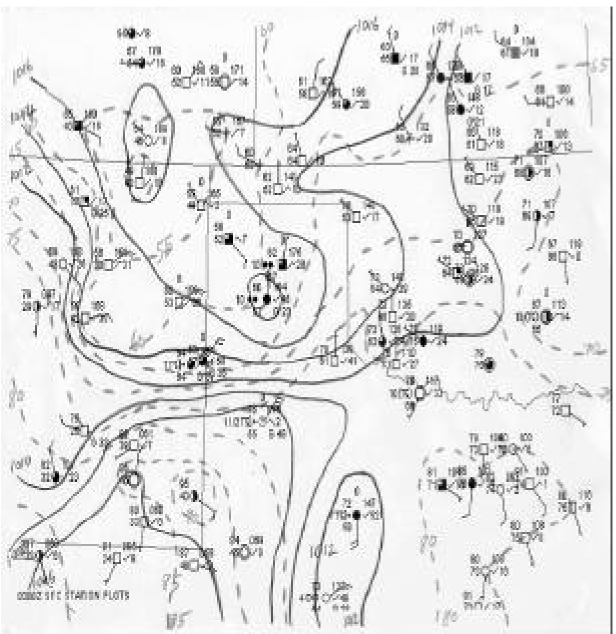

Figure 3. Subjectively analyzed surface map for 0300 UTC. Isotherms dashed every 5 degrees F, isobars solid every 2 mb.

At 0245 UTC storm relative velocity data indicates that the outflow had moved just east of Reese Center on the western edge of Lubbock. Reflectivity at 0256, shown in fig. 2, reveals the well-defined bow structure just west of Lubbock. Shortly after, at 0305 UTC, a wind gust of 91.6 kt was recorded at the West Texas Mesonet site in Reese Center. Concurrently the reflectivity data revealed a significant rear inflow notch to the immediate west of Reese Center at 0305 UTC indicating the possibility of significant momentum flux from mid-levels to the surface enhancing outflow winds.

By 0315 UTC the complex was moving into southern Lubbock County, having interacted with the northwestward moving boundary and accelerating in forward motion. This may be due to the enhanced cold pool that had developed by this time, as evidenced by the mesonet data. According to local balance theory (Rotunno et. al., 1988), if the strength of the cold pool becomes too great, the circulation produced by this feature will overwhelm the low level shear-induced circulation causing the convection to be displaced further from the leading edge of the outflow with time.

Indeed, this appears to be the case on the southern flank of the system, as successive volume scans indicate the outflow becoming progressively detached from new development on the southern flank of the system. However, the eastern flank of the system remains anchored to the outflow that may be due to greater system relative inflow retarding the forward motion of the outflow. Subsequently, the reflectivity pattern increased in aerial coverage and bifurcated as the area of significant rotation drifted slowly eastward with the southern periphery racing southward and weakening.

Throughout the event, an impressive system-relative inflow was maintained per storm relative velocity cross sections. These cross sections also revealed the existence of a well-developed front-to-rear flow elevated above a developing rear inflow jet as the system approached Lubbock County. It is hoped that model simulations will be able to reproduce these features and clarify what mechanisms caused the system to become unsteady.

4. West Texas Mesonet Data

Maybe the most significant characteristic of this event is not particularly the storm's structure, as many bow echoes have been cataloged, but rather the movement of such an intense system through a dense surface observational network such as the West Texas Mesonet. Hourly synoptic scale METAR observations were analyzed to identify features such as mesohighs and boundaries within the region in question (fig.3).

However, it becomes readily apparent from comparing the West Texas Mesonet data and the synoptic data that storm scale features are damped out significantly by the coarser synoptic data. Of course, this would be expected, but the magnitude of damping becomes quite impressive when the 0300 UTC synoptic data is compared to the West Texas Mesonet data at the same time (fig.4). As can be seen, an extensive mesohigh is located near the Amarillo region associated with a broad cold pool which had developed in response to widespread precipitation in that region.

Inspection of the mesonet data, with a deliberately chosen small contour interval, reveals the nose of a well defined mesohigh in association with the locally enhanced cold pool associated with the Lubbock County bow echo. Although one must be careful in deriving small scale patterns off a single observation, it is believed that the Reese Center mesonet observation is reliable at this time as temporal continuity is achieved with 50?F air temperatures making their way into Lynn County, south of Lubbock, by 0400 UTC.

A puzzling feature is the existence of an enhanced pressure gradient field on the eastern edge of the system with the concurrent strongest winds being directed somewhat southeast if not straight south.

Synoptic scale data suggests the large-scale pressure gradient force is directed from north to south, while storm scale features are likely the cause for the enhanced east/west gradient seen in the mesonet data. In particular, a preconvective trough may be the cause of this feature near Lubbock, but temporal continuity has not been verified with this feature so any conclusions must be made with caution.

In the future, such high spatial resolution will prove to be a boon for mesoscale modeling and one hopes that features such as the Lubbock County storm resolved by the network will lead to improved boundary layer representations of phenomena such as mesoscale pressure systems and convective storm/outflow interaction.

5. Conclusions and Future Work

The May 30th high wind event in Lubbock, Texas raises many questions as to the ability of bow echoes that are somewhat transient to produce extreme wind damage. An environment marked by such weak forcing and moderate severe parameters would not be expected to produce such extreme weather, leaving the question as to what dynamics were crucial in generating such large values of kinetic energy. It is hoped that high-resolution numerical simulations of the May 30th event will shed considerable light on why such a weakly forced environment would produce a storm with such extreme wind characteristics. These simulations will be run using MM5 and RAMS mesoscale models in hopes of recreating the bow echo feature responsible for the extreme winds.

Another goal in the simulations is to understand the processes that led to a supercellular mode transitioning to a more linear mode driven by cold pool dynamics. Some research has already begun in this vein (Finley et. al., 2001), but the fundamental dynamics of such a transition are still enigmatic. In particular, can we say that environmental shear or mid-tropospheric humidity variations have anything to do with the transition? How does balance theory handle such a system and its progression? At first glance, it does appear to model the dynamics of the system well as the storm becomes increasingly outflow dominant during its progression into an environment with weaker low-level shear.

Another interesting characteristic of this event is its loose association with current research on extreme wind events and the existence of supercells at some point within the event (Miller and Johns). Although the aforementioned research focused on the ability of supercells to produce the extreme wind damage observed during derechoes, the Lubbock bow echo did originally exhibit supercellular characteristics early in its life cycle with a subsequent long track of wind damage. It is hoped that the research performed on this event will increase our understanding of the dynamics of transient extreme wind events and the part that convective mode transitions might have in this.

6. Acknowledgements

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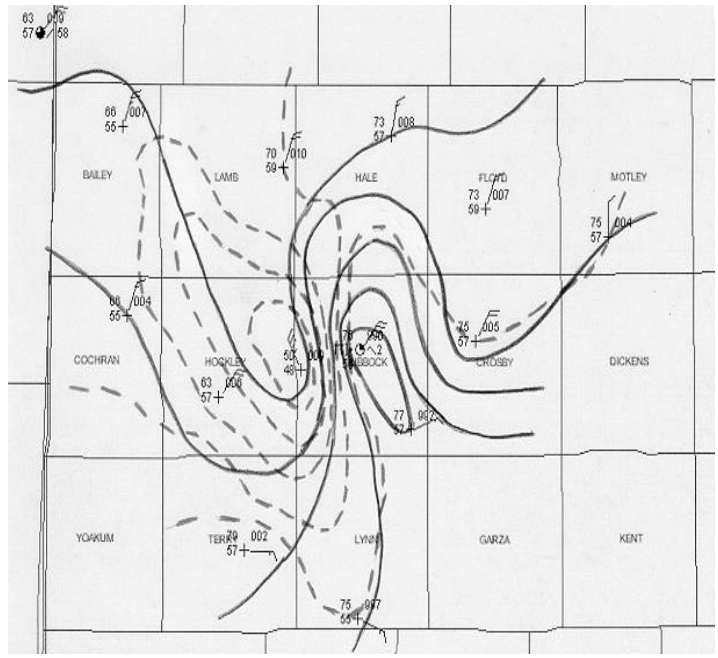

Figure 4. Subjectively analyzed surface map centered on Lubbock for 0300 UTC. Isotherms (dashed) analyzed every 5 degrees F, isobars (solid) analyzed every .4 mb.

7. References

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