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SEVERE WEATHER EVOLUTION ASSOCIATED WITH A BOW ECHO AND A SERIES OF MESOLOWS

Diana M. Blahyj
SUNY – Brockport, NY
and
David A. Imy*
NOAA/NWS/NCEP/Storm Prediction Center
Norman, Oklahoma

1. INTRODUCTION

Fujita (1971) was one of the first to identify the bow echo as a radar indicated reflectivity structure that is associated with damaging winds. The severe winds typically occur near the apex of the bow where winds descending from the rear of the storm result in the low-level reflectivity structure evolving into a concave-shaped echo (Fujita 1978). Przybylinski and Gery (1983) identified additional radar characteristics, such as the weak echo channel, low-level reflectivity gradient and echo top location over the low-level reflectivity gradient as a favorable indication of damaging winds occurring near the bowed portion of the system.

On 12 March 2001, a thunderstorm line with embedded bow echoes and surface mesolows moved from eastern Texas eastward through Louisiana, Mississippi and Alabama. During the early morning hours, wind damage occurred along the bowed portion of the line in central Louisiana. The damaging winds ceased along the bowing portion of the line by mid-morning and the subsequent severe weather occurred in storms co-located with the mesolows. Although supercells developed ahead of the line, there were no tornadoes with these storms, but 11 tornadoes occurred within the line. This paper details key mesoscale features that affected severe weather evolution on this day.

2. THE SYNOPTIC/MESOSCALE ENVIRONMENT

At 1200 UTC on 12 March 2001, a surface cold front/trough and an accompanying line of thunderstorms stretched from southeastern Texas northeastward through west central Louisiana into western Arkansas (Fig 1). One mesolow was located in southeast Texas with another in west central Louisiana. A warm front extended from the Louisiana low, eastward into southern Mississippi. Temperatures in the warm sector ranged from the mid-60s to near 70 degrees F with dewpoints only a couple of degrees lower.

At 850 mb, ahead of the thunderstorm line, 35-45 kt southerly winds were advecting moisture rapidly northward across the lower Mississippi Valley. A cold front was located west of the surface front/ trough with westerly winds at 20 kt behind the front. However, a 50 kt wind was observed at Shreveport, LA (SHV), likely the result of a rear inflow jet from nearby convection. A broad 500 mb trough was situated over the central United States, while a shortwave trough was moving northeastward from Texas toward the central gulf coastal states within a band of 50-60 kt winds. At 250 mb, the polar jet extended from western Texas northeastward into the mid-Mississippi Valley, while the subtropical jet was located from the Louisiana to Florida coasts. This jet structure contributed to strong difluence aloft across the central gulf states.

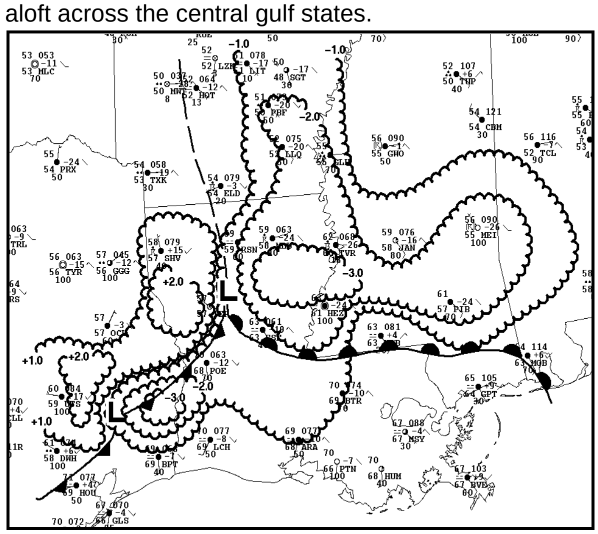

Figure 1 Surface analysis at 12 UTC on 12 March 2001. Scalloped lines are 2 hourly isoallobaric changes (mb).

Using the most unstable parcel on the soundings at Lake Charles, LA (LCH) and Slidell, LA (LIX) (Fig. 2), CAPE values were around 2500 J/Kg with lifted Index values near -4. Both soundings had strong winds throughout the lower troposphere resulting in surface to 6 km shear of 55 to 60 kt.

However, the winds in the lower 3 km at LCH exhibited only modest veering with height resulting in a 0-3 km shear of 20 kt, while pronounced veering in the lowest km and stronger winds at LIX increased the 0-3 km shear to near 40 kt. Using the actual storm motion of 250 degrees at 45 kt, the 0-3 km storm relative helicity (SRH) values at these two sites ranged from 250 m^2/s^2 at LCH to 400 m^2/s^2 LIX.

Corresponding author address: David A. Imy, NOAA, NWS Storm Prediction Center, 1313 Halley Circle, Norman, OK 73069-8493; e-mail: david.imy@noaa.gov

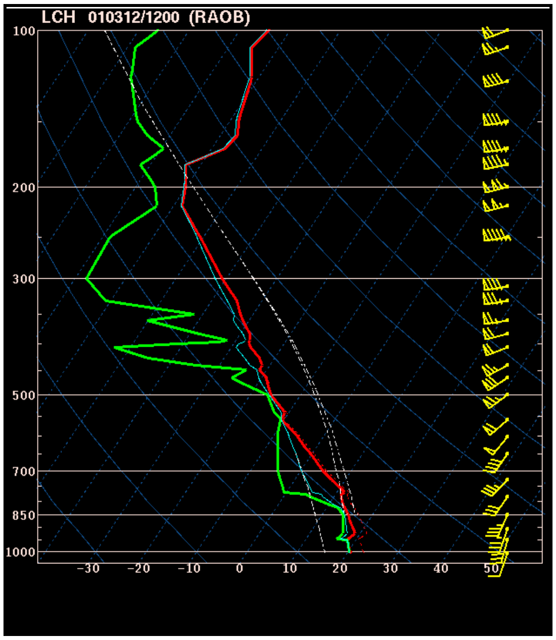

Figure 2a LCH 12Z sounding on 12 March 2001.

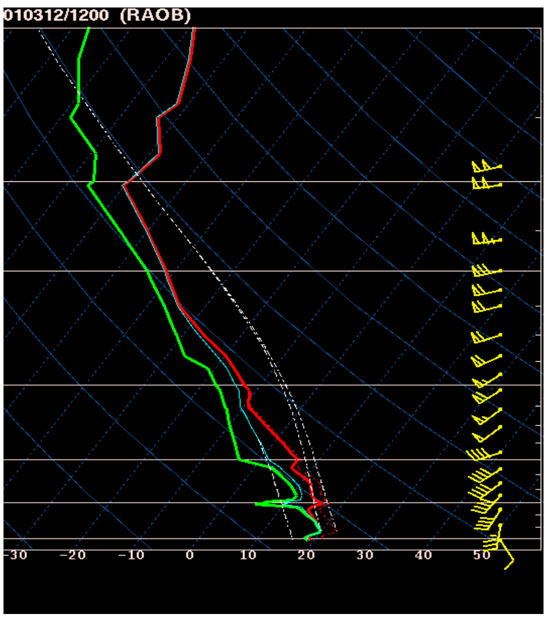

Figure 2b LIX 12Z sounding on 12 March 2001.

Surface pressure falls occurred ahead of the thunderstorm line, with rises behind it (see Fig 1). Some of the pressure changes were likely due to dynamical forcing associated with the Texas shortwave trough. Additional pressure falls north of the warm front were caused by warm advection, but the more concentrated isoallobaric fall/rise couplets appeared to be associated with the mesolows.

3. MESOLOW EVOLUTION

A mesolow is a sub-synoptic low pressure system that is located along a surface trough, cold front, etc. The diameter of a mesolow circulation is approximately 15-70 nm (Magor 1959). Surface pressure falls may be observed 1-2 hours before a mesolow nears a given location, and rises occur 1 to 2 hours after the mesolow passes. Although the mechanism for their development is unclear, their existence is known for enhancing the potential of severe weather (Doswell 1982).

Magor (1959) stated that given the spacing of surface observation stations in the United States, the chances of intercepting and following mesolows on a surface synoptic chart are extremely small. Although more observational and mesonet sites have been added since the late 50s, following mesolows is still difficult, especially if they occur in areas with a low density of observation sites. After this event, hourly surface analysis was performed from 1000 UTC to 2000 UTC. This analysis included every 2F degree isotherms, 2F isodrosotherms and 2 hourly isoallobaric changes. The individual archive II radar data at Jackson, MS (JAN), LIX and Mobile, AL (MOB) were also used to assist in the identification process of mesolows, especially when they were located between observation sites.

The WSR-88D storm relative velocity and reflectivity structures suggested that most of the mesolows were accompanied by supercell storms. The algorithm-detected mesocyclones, base reflectivity and storm relative velocity products were used to identify rotation.

Although a number of mesolows were identified, a majority of the severe weather occurred with four of the them. In general, these lows moved eastward within the thunderstorm line at 45 kt with identifiable lifetimes from 2 to 10 hours. Fig. 3 shows a track of the four primary mesolows.

The first mesolow was located at the intersection of the thunderstorm line and warm front from 1000 UTC - 1600 UTC, then moved north of the warm front, and occluded. This mesolow was identifiable for 10 hours, but produced all of its severe weather (12 wind reports) between 1200 UTC and 1700 UTC.

Mesolow 2 formed in southeast Texas around 1100 UTC, moved into southwest Louisiana and then dissipated by 1500 UTC. This mesolow remained south of the warm front, and all four of its severe weather events (3 hail and 1 wind) occurred between 1400 UTC-1500 UTC.

Mesolow 3 formed along the thunderstorm line around 1500 UTC near the Mississippi/Louisiana state line, and persisted for five hours before weakening in southeastern Alabama. This mesolow was the only one of the four that was located to the south, north, and at the triple point during its lifetime. This mesolow was associated with more than half of the severe weather events within the line. While mesolow 3 was south of the warm front, it produced 7 tornadoes, and 8 wind events. When it was located at the triple point, 14 severe weather events (1 tornado, 13 wind) occurred, but none were located north of the triple point.

Mesolow 4 formed in southeastern Louisiana near the Mississippi state line around 1600 UTC and lasted about 2 hours. Even though this mesolow was short-lived, 3 tornadoes and 1 wind event occurred in association with this system.

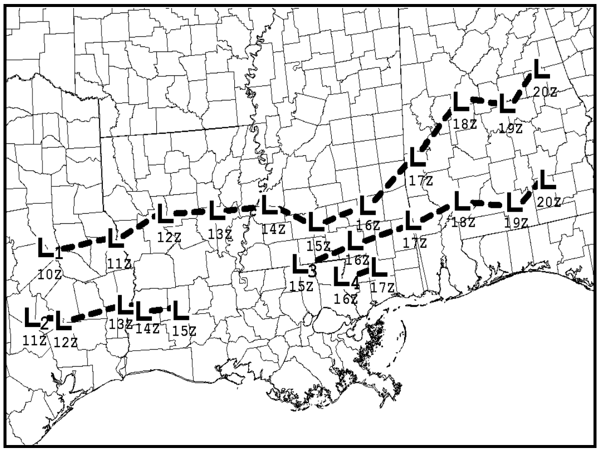

Figure 3 Track of primary mesolows on 12 March 2001.

4. SEVERE WEATHER AND THE COLD POOL

Although thunderstorm lines with embedded bow echoes typically produce most of their severe weather along the bowing portion of the line, three-fourths of the severe weather on this day occurred in storms associated with mesolows. Also, as a general rule of thumb, when a thunderstorm line is moving at least 40 kt through an unstable, thoroughly mixed environment, the bowing portion of the line is likely to produce severe winds (Johns, personal communication). This held true while the line was moving through Louisiana, but the wind damage along the bow ceased as it moved through Mississippi and Alabama, even though the line continued to move at 45 kt. What caused the character of the severe weather to change?

The wind damage associated with the bowing portion of the line occurred in Louisiana with the presence of a 50 kt rear inflow jet (observed on vad wind profile at SHV between 1100 UTC and 1200 UTC and Alexandria, LA between 1200 UTC-1300 UTC). Also, the surface theta-e analysis showed the presence of a strong cold pool gradient behind the line (Fig 4). The severe weather occurred along the bowing portion of the line when both the cold pool gradient and rear inflow jet were strong.

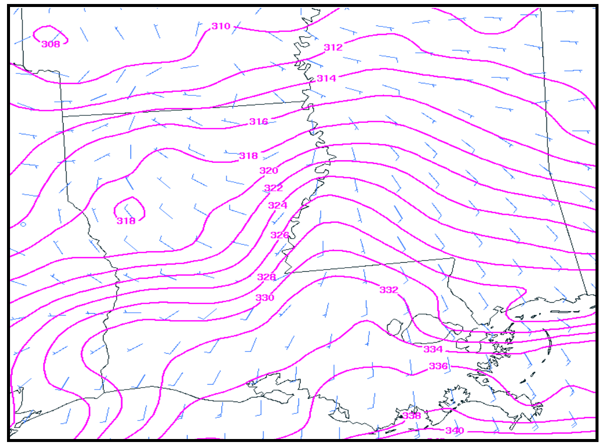

Figure 4 Theta-e and boundary layer winds at 1300 UTC

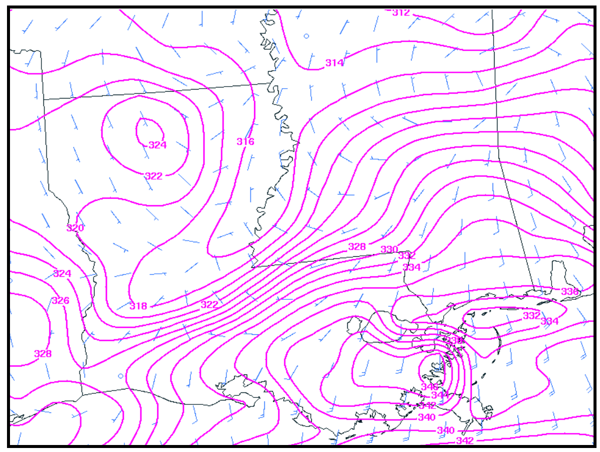

Figure 5 Theta-e and boundary layer winds at 1600 UTC.

The theta-e analysis indicated that the cold pool gradient weakened as it moved eastward from Mississippi into Alabama after 1500 UTC (Fig 5), the same time the wind damage ceased along the bowing portion of the line. Although strong rises were observed behind the front, the largest falls were located across portions of eastern Mississippi (Fig 6). The LIX vad wind profile between 1700 UTC and 1800 UTC showed that the rear inflow jet had decreased to 30 kt (Fig 7). Although the most pronounced portion of the bow and pressure falls were located north of LIX, no severe winds were reported with the bowing portion of the line.

Although severe weather associated with the thunderstorm line began at 1200 UTC, no tornadoes occurred until after 1500 UTC. By this time, temperatures had warmed several degrees. Also, the line had moved eastward into an environment where the morning soundings and late morning vad wind profiles showed the low level shear was stronger than in areas

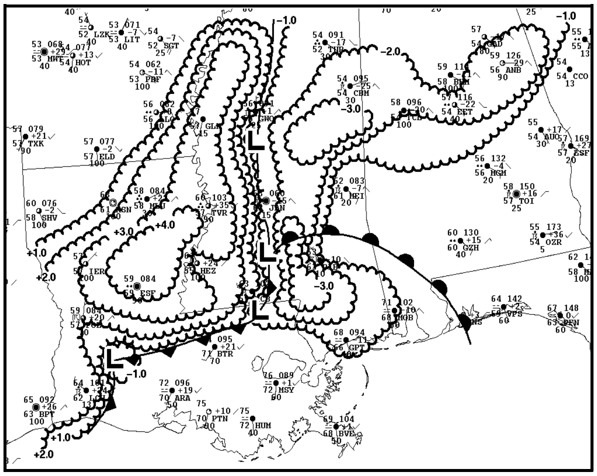

Figure 6. Surface analysis at 15 UTC on 12 March 2001. Scalloped lines are 2 hourly isoallobaric changes (mb)

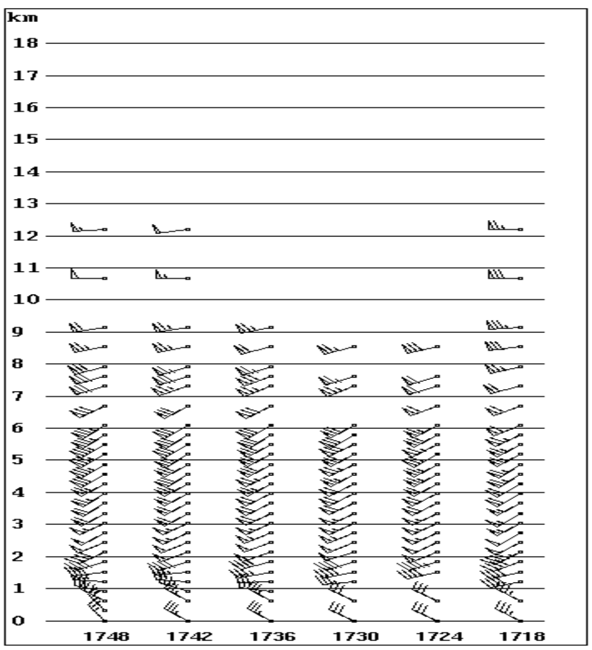

Figure 7 Vad Wind Profile from 1718-1748 UTC at LIX.

the line had moved through earlier in the day. Although the environment was more favorable for tornadoes, the tornado development within the line also appeared to be related to the strength of the cold pool gradient and rear inflow jet. As an analogy, if the RFD in a supercell dominates the updraft, the cold air undercuts the updraft and limits tornado development (Brooks, et al. 1994). Similarly, when mesocyclonic circulations were present within a line, tornadoes did not occur when the cold pool gradient and rear inflow jet were strong, as these factors also likely undercut the updraft and inhibited tornado development. However, with the weaker cold pool gradient and rear inflow jet in a supercell environment, the updraft/downdraft were able to maintain a better balance for tornadogenesis.

5. SUMMARY

A line of thunderstorms with embedded bow echoes and mesolows moved from eastern Texas eastward through Louisiana, Mississippi, and Alabama on 12 March 2001. A strong cold pool gradient and rear inflow jet accompanied the line through Louisiana, with damaging winds occurring along the bowing portion of the line. After the cold pool gradient and rear inflow jet weakened, the severe weather was concentrated near the mesolows.

A majority of the severe weather events that occurred along the bowing portion of the line were wind damage. No tornadoes, however, occurred until after 1500 UTC. After 1500 UTC, temperatures had warmed slightly, and the line had moved into an environment with stronger low-level shear. No tornadoes occurred with the supercells located ahead of the line, but 11 were reported with storms located within the line. The weaker cold pool gradient and rear inflow jet may have allowed the mesolow storms within the line to acquire a better balanced updraft/downdraft structure that was more favorable for tornado development.

6. ACKNOWLEDGEMENTS

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