P2.2 THE IMPORTANCE OF ACARS DATA IN EVALUATING THE NEAR-STORM ENVIRONMENT OF A NOCTURNAL QLCS EVENT

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1. INTRODUCTION

During the early morning hours of 2 May 2006, a quasi-linear convective system (QLCS) moved across southern Indiana and central Kentucky, affecting the County Warning Area (CWA) of the National Weather Service office in Louisville, KY (Fig. 1). Numerical model output and observational data indicated a marginally severe weather threat with the line of thunderstorms over the western portion of the CWA overnight, though the surface-based instability and severe weather threat was expected to diminish with eastward extent. However, as convection moved into central Kentucky, damaging surface winds occurred, as well as an EF-0 tornado around 5:30 am EDT.

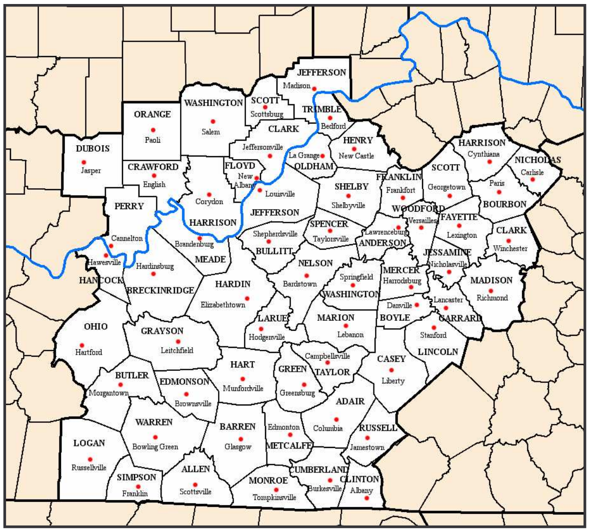

Fig. 1. Map of the CWA of the Louisville National Weather Service office.

The motivation in studying this event was to determine why severe weather occurred when the QLCS moved into a supposed stable environment. It is often assumed by operational forecasters that surface-based convection more readily occurs during peak mixing hours, which is typically during the day. In principle, this is a rather safe assumption since boundary-layer stability usually increases during minimum mixing hours, or at night. Contrary to expectations, the boundary layer in this case became more unstable as the night progressed, allowing for the severe weather to occur.

Although this case may have been atypical, nocturnal events have in the past produced severe weather in environments presumed to be rather stable. Determining what available data could have identified the destabilization during the 2 May 2006 event became the focus of this study. Since there is a lack of trained spotter reports at night, it is necessary that operational forecasters use all available data to best analyze the near-storm environment. It will be shown that upper-air soundings from the Aircraft Communications Addressing and Reporting System (ACARS) can provide such vital assistance, as it did in retrospection during the 2 May 2006 event.

2. ENVIRONMENTAL AND RADAR DISCUSSION

Though the atmosphere over the lower Ohio Valley was weakly unstable during the very early morning hours of 2 May 2006 (approximately 800 $\mathrm{Jkg^{-1}}$), a moderately strong low-level jet of 20 $\mathrm{ms^{-1}}$ helped advect warm and moist air northeastward along and ahead of an approaching inverted surface trough (not shown). All of this, combined with a negatively-tilted 500hPa shortwave trough over central Illinois, provided enough dynamics to overcome the lack of strong instability and form a QLCS. This line of thunderstorms was producing marginally severe wind gusts before it entered the Louisville CWA (Fig. 2). From Fig. 2, it can be seen that the QLCS had a bowing segment, which is characteristic of enhanced

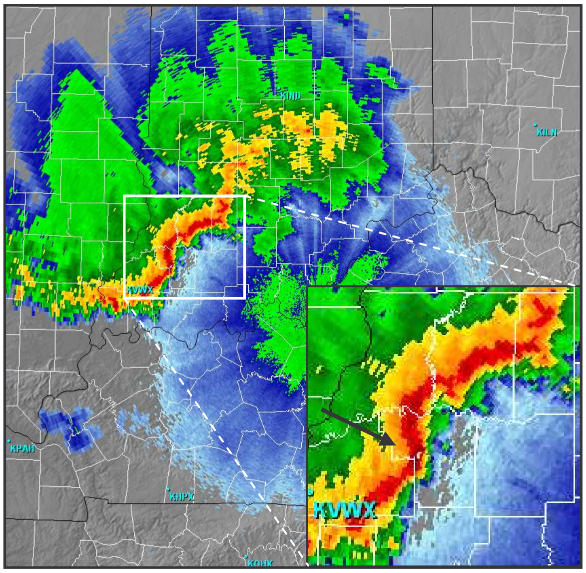

Fig. 2. Base reflectivity image from the KLVX WSR-88D Doppler radar valid at 0620 UTC 2 May 2006. The inset enlarging the QLCS shows the embedded bowing segment (indicated by black arrow).

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surface winds and often times resultant damage (Fujita 1978, Przbylinski 1995). However, only one report of wind damage was received within the CWA in Indiana. This led operational forecasters to believe that the QLCS was weakening as it crossed into Kentucky, which seemed justifiable given that the gust front was advancing ahead of the main line (not shown).

As the QLCS advanced into Kentucky, the line became much less defined, lending support to a weakening QLCS. Figure 3 shows that the reflectivity gradient weakened considerably, along with the strong, leading-line reflectivities, making the line appear notably disorganized. In fact, the outflow boundary is difficult to see in base reflectivity, though it is recognizable in the velocity data (Fig. 3).

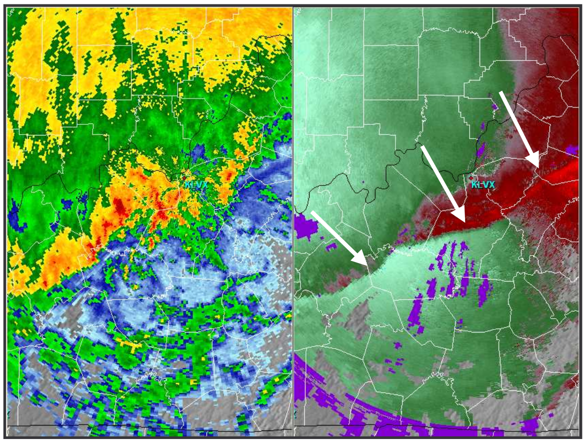

Fig. 3. Base reflectivity (left) and storm-relative velocity (right) valid at 0910 UTC 2 May 2006. Arrows indicate the location of the outflow boundary.

Even though the QLCS appeared disorganized around 0910 UTC, damaging winds and an EF-0 tornado occurred less than 30 minutes later about 50 km south of the KLVX radar (Fig. 4). In viewing the radar data, it appeared that two circulations, or mesovortices, formed along the leading edge of the supposed dissipating QLCS, very near the outflow boundary intersection with the QLCS itself. Though the mesovortices could be considered unidentifiable from reflectivity, lining their tracks up with the resultant damage indicated that they were indeed responsible for the weak tornado and straight-line wind damage, similar to previous findings (Lese 2006; Wheatley et al. 2006).

It is often difficult to gather or receive real-time severe weather reports with nocturnal events, despite having a reliable, trained spotter network. Although this was generally true with this case, it is essential that operational forecasters use all available observational data, especially at night, to accurately analyze the near-storm environment. On the morning of 2 May 2006, ACARS soundings provided that necessary additional data set.

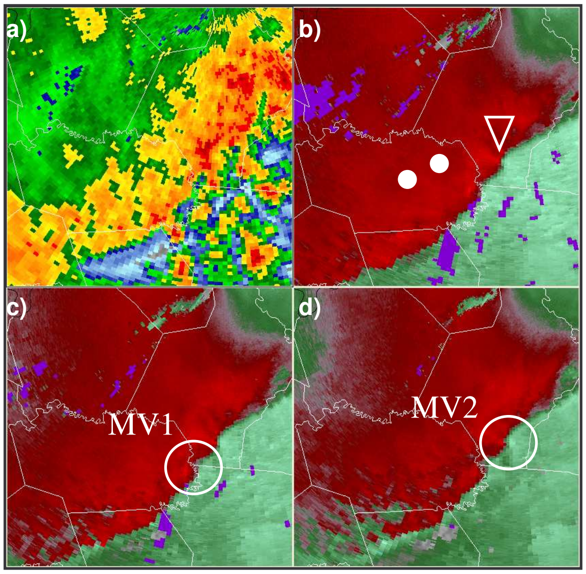

Fig. 4. A four-panel plot of (a) 0.5° base reflectivity, (b) 0.5° storm-relative velocity, (c) 0.9° storm-relative velocity, and (d) 1.3° storm-relative velocity, all valid at 0940 UTC 2 May 2006. The locations of the tornado (inverted triangle) and straight-line wind damage (white dots) are identified in (b), while the location of two mesovortices (white circles) are identified in (c) (MV1) and (d) (MV2).

3. RESULTS OF ACARS SOUNDING DATA

ACARS is a digital data link system for transmission of small messages between aircraft and ground stations via radio or satellite. In the early 1990s, some aircraft were equipped with instruments to provide sounding information which could be transmitted through ACARS. The United Parcel Service (UPS), with its main aircraft hub in Louisville, Kentucky, first reported sounding data in 1992, with high-resolution data delivered in 1994 (R. Baker 2007, personal communication). Some aircraft were fitted with moisture sensors as early as 1997 and have since been updated to provide more accurate information, though the most error-free and highly accurate sounding data are derived from the temperature and wind profiles (Mamrosh et al. 2002; Benjamin and Schwartz 1999).

Most ACARS data are gathered between 7.6 km – 13.7 km, where data are distributed fairly uniformly over the continental United States. Below 7.6 km though, data are concentrated near major hubs (Moninger et al. 2003). This provides the Louisville National Weather Service office with ample soundings, especially at night when most UPS aircraft arrive at and depart from the Louisville International Airport. On the morning of 2 May 2006, there were over 50 soundings available in the four hours prior to the passage of the QLCS.

During the 2 May 2006 event, forecasters on duty at the Louisville NWS office viewed one of the many UPS soundings from the Louisville International Airport, prior to the QLCS's arrival at the airport. The sounding was taken at 0705 UTC from an airplane descending from the south, sampling the low-level atmosphere in the vicinity of where the QLCS eventually produced wind damage and the tornado. This sounding was 75 km southeast of the approaching QLCS, or 75 minutes prior to the arrival of the QLCS at the airport. The sounding recorded a temperature of 16.2 °C at the surface, with a temperature of 18.0 °C at 944 hPa (Fig. 5a). This increase in temperature, or low-level inversion, suggested that a stable boundary layer was in place ahead of the QLCS, leading on-duty forecasters to believe that a severe weather threat was nonexistent.

According to the automated surface observation station (ASOS) at the airport, the QLCS passed through at 0817 UTC. However, before this occurred, a descending aircraft ACARS sounding at 0804 UTC (following a similar trajectory as the previous sounding) showed the surface temperature had increased to 18.1 °C while the temperature at 948 hPa had decreased to 17.0 °C (Fig. 5b), no longer indicating a substantially stable boundary layer.

It is important to note that although real-time ACARS soundings were available, these originated at the Louisville International Airport, approximately 95 km north of the tornado and wind damage. However, downstream from the airport, closer to where the tornado and wind damage occurred, the same behavior was identified when compared to Local Analysis and Prediction System (LAPS) sounding data and mesonet observations. In viewing a LAPS sounding from Elizabethtown, Kentucky (about 25 km north of the tornado location), temperatures from 0800–0900 UTC decreased at 900 hPa prior to the QLCS's arrival (not shown). Also, the Elizabethtown mesonet observation displayed a similar temperature to the Louisville International Airport, but with an increase in dewpoint. The combination of the decreasing temperature at 900 hPa and the increasing dewpoint ahead of the QLCS indicated a thinning convective inhibition (CIN) layer, and that the boundary layer was not stabilizing as predetermined. The boundary layer was actually becoming more unstable, and storms were more likely to become surface-based in nature.

Had forecasters on duty monitored the numerous ACARS soundings available on the morning of 2 May 2006 as opposed to viewing just one sounding ahead of the QLCS, it is possible that they could have identified the thinning CIN, recognizing a downstream severe weather threat still existed, contrary to the initial assessment. This would have led forecasters to recognize the destabilization, making them better prepared in warning for the damaging winds and the EF-0 tornado that occurred further downstream.

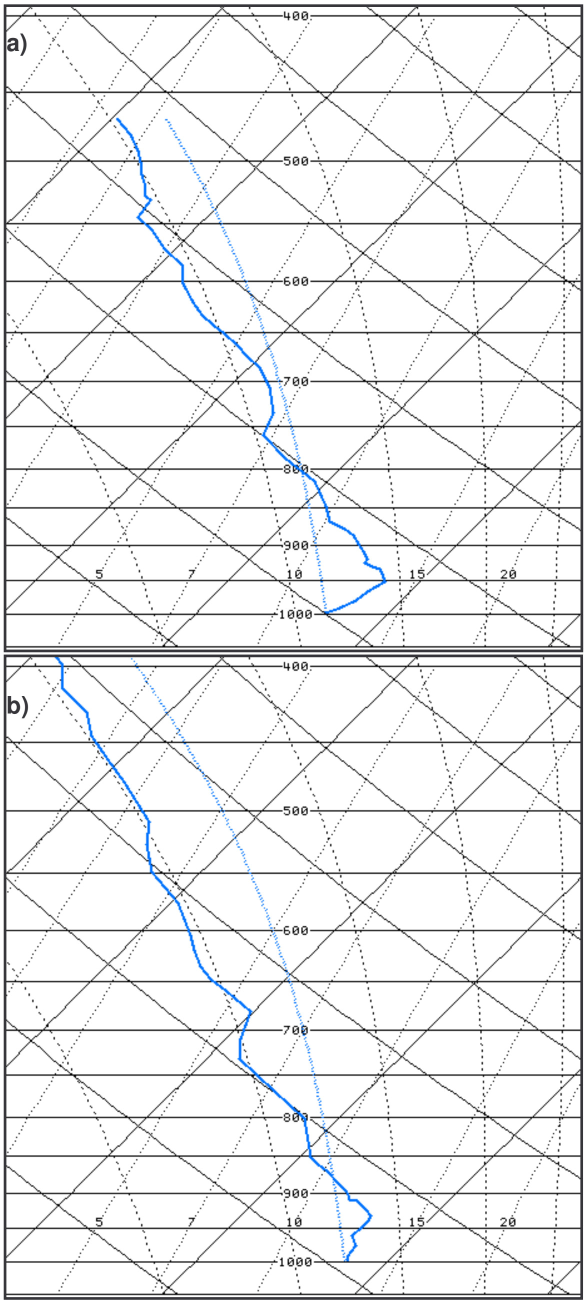

Fig. 5. ACARS temperature soundings valid at (a) 0705 UTC and (b) 0804 UTC.

4. CONCLUSIONS

It is generally assumed by operational forecasters that surface-based convection more readily occurs during peak mixing hours, which is typically during the day time. Thus, nocturnal environments are usually less suited for surface-based convection since the low-level atmosphere is typically more stable at night due to surface cooling and the development of a low-level inversion. In general, these stable boundary layers can prevent damaging winds from mixing down to the surface, and often this is the case at night.

However, it has been shown that despite a stable boundary layer, a QLCS produced damaging winds and a tornado during the early hours of 2 May 2006.

Idealized simulations have verified that low-level stable layers can reduce the damaging wind potential in QLCSs (Cunningham and Atkins, 2006). Further, Cunningham and Atkins showed that the stable layer can mitigate the formation and evolution of mesovortices. However, those experiments dealt with strong stable boundary layers. In the 2 May 2006 case, the CIN was not that strong, though it was indeed present ahead of the QLCS, leading forecasters on duty to misinterpret the boundary layer environment. As it was shown, the CIN weakened atypically as the night progressed. However, on the last valid ACARS sounding prior to the QLCS passage (Fig. 5b), there was a small amount of CIN still present ahead of the QLCS. Even if forecasters noted this weak CIN, they may have still characterized the low-level environment as stable, and have assumed the storms were elevated in nature. Even with this weak CIN, the mesovortices, perhaps aided by the outflow boundary intersecting the line, were still able to produce damaging wind gusts and a weak tornado. Therefore, it is suggested that operational forecasters avoid the assumption that all convection is elevated when weak CIN exists, especially if the low-level environment is *trending* toward instability as it was shown via ACARS soundings in this case. Forecasters should be wary of a weakening, or thinning, boundary layer inhibition, which may be a precursor for severe winds mixing down to the surface. To help remember this, forecasters may want to presume that in some cases, *a thin CIN = damaging wind*.

Because of the great availability of ACARS soundings prior to the QLCS passage on 2 May 2006, forecasters could have identified the thinning CIN in the many ACARS soundings that existed, and could have increased their awareness in identifying that the QLCS was capable of producing severe weather. These ACARS soundings are fantastic supplements to other observational data available to operational forecasters. These soundings could have been considered necessary in correctly analyzing the stability of the low-level atmosphere during the night time hours of the 2 May 2006 event. Viewing one ACARS sounding proved insufficient, even though the sounding viewed was close in time and proximity to the QLCS passage. Therefore, it is suggested that forecasters use ACARS soundings to identify *trends* in the near-storm environment instead of the environment at one time. Thanks to the increasing number and coverage of these ACARS soundings (Moninger et al. 2003), operational forecasters are highly encouraged to capitalize on this great availability, especially during nocturnal events when observational data and spotter reports may be lacking.

5. REFERENCES

Benjamin, S. G., and B. Schwartz, 1999: Accuracy of ACARS wind and temperature observations determined by collocation. *Wea. Forecasting*, **14**, 1032-1038.

Cunningham, J. J., and N. T. Atkins, 2006: The influence of low-level stable layers on damaging surface winds within bow echoes. Preprints. *23rd Conf. on Severe Local Storms*, St. Louis, MO, Amer. Meteor. Soc.

Fujita, T. T., 1978: Manual of downburst identification for project NIMROD. SMRP Research Paper 156, University of Chicago, 42 pp.

Lese, A., 2006: Observations and quantification of low-level mesovortex evolution within the 4 July 2004 southwest Missouri high wind event. Preprints, *23rd Conf. on Severe Local Storms*, St. Louis, MO, Amer. Meteor. Soc.

Mamrosh, R. D., R. Baker, and T. Jirikowic, 2002: A comparison of ACARS WVSS and NWS radiosonde temperature and moisture data. Preprints. *Sixth Symposium On Integrated Observing Systems*, Orlando, FL, Amer. Meteor. Soc., 275-280.

Moninger, W. R., R. D. Mamrosh, and P. M. Pauley, 2003: Automated meteorological reports from commercial aircraft. *Bull. Amer. Meteor. Soc.,* **84**, 203-216.

Przybylinski, R. W., 1995: The bow echo: observations, numerical simulations, and severe weather detection methods. *Wea. Forecasting*, **10**, 203-218.

Wheatley, D. M., R. J. Trapp, and N. T. Atkins, 2006: Radar and damage analysis of severe bow echoes observed during BAMEX. *Mon. Wea. Rev.*, **134**, 791-806.