JP1.3 ANTICIPATING AND MONITORING SUPERCELL MOTION FOR SEVERE WEATHER OPERATIONS

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1. INTRODUCTION

Modeling studies since the early 1980s, field programs, and empirical studies indicate that supercell motion can be anticipated prior to, and monitored during, severe weather operations (summarized in Bunkers et al. 2000). These abilities can translate into better forecasts, warnings, and emergency manager and media preparedness.

Despite additional conference papers (e.g. Bunkers and Zeitler 2000) and computer-based training (UCAR 1996, 1999), use of new supercell motion forecast techniques remains limited to the National Weather Service (NWS) Storm Prediction Center (SPC) and a few Warning and Forecast Offices (WFOs).

There may be a number of reasons for the lack of use, including: simple unawareness, incomplete or inadequate training, lack of confidence in the new techniques, or perceived lack of real-time data for the determination of shear, storm-relative helicity (SRH), and other derived parameters. This study addresses the last reason—perceived lack of real-time data. Section 2 identifies near-real- or real-time sources of wind profile data. Section 3 contains two case studies of supercell motion diagnosed or monitored by data sources listed in Section 2. Section 4 contains conclusions and recommended actions for operational forecasters.

2. SOURCES OF WIND PROFILE DATA

2.1 Rawinsondes (RAOBs)

A scan of NWS WFO forecast discussions shows that radiosonde observations (RAOBs) are still the most popular source of data for upper-air information. This is understandable from the standpoint of RAOBs being the traditional data source spanning the advent of modern meteorology after World War II. In addition, RAOBs have the positive attributes of 1) in-situ data, 2) concurrent thermodynamic and wind data, and 3) well-known and minimized equipment and acquisition errors. Unfortunately, RAOBs have two substantial limitations, especially in regards to forecasting and monitoring severe convection: 1) poor spatial resolution [~100 sites in the Continental United States (CONUS)], and 2) poor temporal resolution (observations at 12-h intervals). Many individual storms and entire mesoscale convective systems (MCSs) can initiate, mature, and dissipate without being detected by the RAOB network. Forecasters attempt to remedy these deficiencies by modifying RAOBs with data to represent the current or forecast (temporal), and/or nearby (spatial) environment. Doswell (1991) discussed some of the pitfalls in these modifications, and Brooks et al. (1994) discussed the notion of proximity soundings. Overall, RAOBs are the best source of data if spatially and temporally nearby. In many instances this is not the case.

2.2 Wind Profilers

The Wind Profiler Demonstration Network (WPDN) provides a remotely sensed source of wind profile data, primarily across the Great Plains. The primary advantages of the WPDN are high temporal resolution, good spatial resolution within the network, and good vertical resolution. However, disadvantages include very few sites outside the Great Plains (nearly all sites between 30 and 45 degrees north latitude and 85 and 110 west longitude), precipitation attenuation, and contamination from organic sources such as bird movements. Further information can be found at:
http://www.profiler.noaa.gov/profilerReferencces.html.

2.3 WSR-88D Vertical Wind Profiles (VWPs)

WSR-88D VWPs are a remotely sensed source similar to the WPDN in providing high temporal resolution wind data. They also share many of the same limitations due to precipitation attenuation and biologic contamination. The greatest disadvantages though are frequent lack of data above 7620 m, remote sensing limited to within 30 km, and no straightforward numeric export format for ingest into sounding/hodograph programs.

2.4 ACARS

Aircraft Communication Addressing and Reporting System (ACARS) observations provide a growing source of wind profile data. The advantages of ACARS data include in-situ, fast-response sensors, high vertical resolution, and on some aircraft, concurrent temperature and dewpoint observations. Temporal resolution is good near hub airports (e.g., LAX, ORD, DFW), but poor over the bulk of the CONUS except at altitudes above 7.5 km (~25,000 ft). Free data access is restricted to airlines, NOAA, and research groups, thereby limiting the utility and applications of ACARS data. Further details can be found at:
http://acweb.fsl.noaa.gov.

2.5 Model Analysis/Forecasts

Another growing source of wind profile data are model analyses and forecasts. In fact, many small operating units such as WFOs and universities regularly run local models allowing for customization of resolution, domain, and physics. In general, model analyses are good, especially for pre-convective environment. Studies by Thompson and Edwards (2000), and others (see http://maps.fsl.noaa.gov), have shown fair to good agreement between model analysis profiles and nearby RAOBs. Excellent horizontal, vertical, and temporal resolution can be tuned to provide data in or close to the convective area of interest.

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However, disadvantages include errors introduced in the analysis or forecast process, which can lead to erroneous fields and hence little or no useful information.

2.6 Data Sources Summary

In general, observed data are considered higher quality than model analyses or forecasts. Similarly, in-situ data are preferred over remotely sensed observations. Finally, close temporal and spatial proximity usually represents the near-storm environment better than observations further away. Table 1 provides a subjective summary of these data types.

Table 1. Subjective summary of various aspects of the wind profile data discussed in section 2.

	Spatial/Temporal Proximity	Data Quality
Model Analyses/ Forecasts	Excellent	Poor to Good
WSR-88D VWP	Good	Fair to Good
ACARS	Good (near hubs) Poor (elsewhere)	Fair to Good
Wind Profilers	Fair (Great Plains) Poor (elsewhere)	Fair to Good
RAOBs	Fair	Good to Excellent

3. EXAMPLE CASES

3.1 Southeast Texas – May 30, 1999

The Fort Bend County Supercell of May 30, 1999 was one of several which formed as part of a "northwest flow" event, referring to winds from 270 to 360 degrees at or above 3000 m in response to an upper-level longwave ridge upstream and trough downstream of the convective area. These events have atypical hodographs as defined by (Bunkers et al., 2000), resulting in values of storm-relative helicity and other parameters derived from it to be unrepresentative of supercell potential when the storm motion is estimated with non-Galilean invariant methods. The supercell produced two reports of 1.9 cm hail, one tornado (which destroyed a barn and numerous trees and power poles) and a flash flood (waist deep water in one subdivision).

The mean supercell motion was from 12 degrees at 7.2 m s^{-1}. Local vernacular for this movement is a "southwest-moving supercell"—implying some special class of supercell. In reality, the supercell is moving right of the mean shear vector—the same as a typical upper-right quadrant hodograph supercell—except the shear vector is rotated roughly 90 degrees clockwise in the mean northwest flow. Figures 1 through 4 show hodographs derived from different sources: (i) the 1200 UTC 5/30/1999 Corpus Christi (CRP), TX, RAOB (~12 hours before the event); (ii) the 0000 UTC 5/31/1999 Lake Charles, LA, (LCH) RAOB (concurrent with the event); (iii) the 2300 UTC 5/30/1999 MAPS analysis sounding nearest to Houston Hobby Airport (HOU); and (iv) the 0014 UTC 5/30/1999 Houston/Galveston WSR-88D (KHGX) VWP.

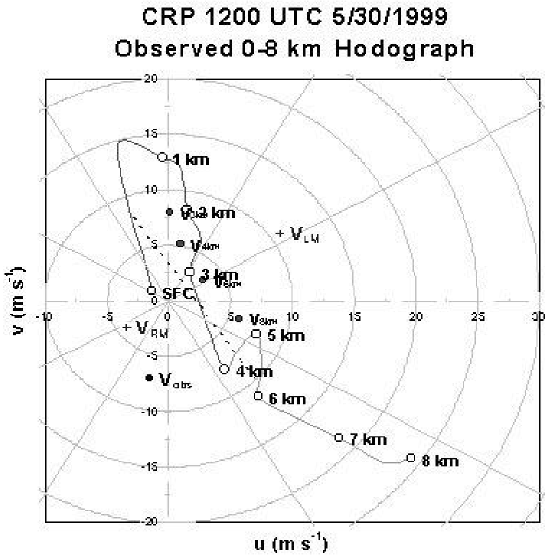

Fig. 1. The 1200 UTC 5/30/1999 CRP RAOB hodograph. V_{LM} is predicted left-moving supercell motion from the method in Bunkers et al. (2000). V_{RM} is the predicted right-moving supercell motion. V_{OBS} is the observed supercell motion.

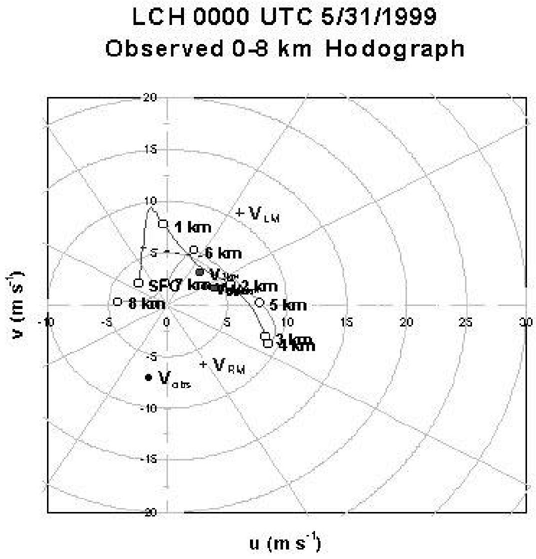

Fig. 2. Same as Fig. 1, except for the 0000 UTC 5/31/1999 LCH RAOB hodograph.

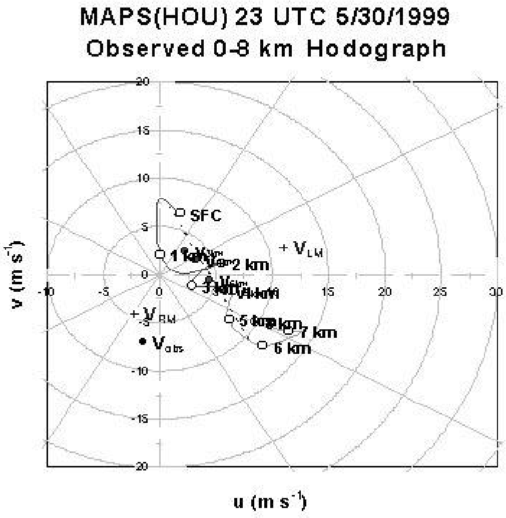

Fig. 3. Same as Fig. 1, except for the 2300 UTC 5/30/1999 MAPS (HOU) hodograph.

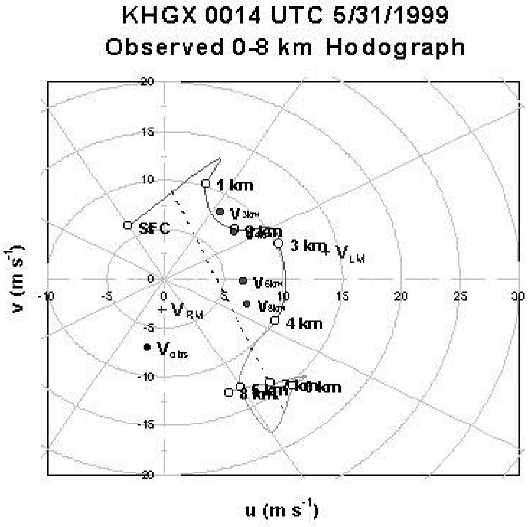

Fig. 4. Same as Fig. 1, except for the 0014 UTC 5/31/1999 KHGX VWP hodograph.

Table 2. 0-6 km total shear (U_s), bulk shear (U_{bs}) and 0-3 km storm relative helicity (SRH) for potential storm environment data sources.

	0-6 km U_s	0-6 km U_{bs}	0-3 km SRH
12 UTC LCH	31.0 ms^{-1}	5.7 ms^{-1}	105 m^{2}s^2
12 UTC CRP	46.8 ms^{-1}	12.8 ms^{-1}	120 m^{2}s^2
00 UTC LCH	35.0 ms^{-1}	5.7 ms^{-1}	183 m^{2}s^2
00 UTC CRP	27.4 ms^{-1}	21.6 ms^{-1}	100 m^{2}s^2
23 UTC MAPS	29.4 ms^{-1}	15.7 ms^{-1}	15 m^{2}s^2
23 UTC RUC	33.7 ms^{-1}	18.5 ms^{-1}	122 m^{2}s^2
0014 UTC KHGX	48.9 ms^{-1}	21.5 ms^{-1}	220 m^{2}s^2

The 0014 UTC KHGX VWP had the smallest predicted motion error – although any of the data sources would have provided a reasonable estimate of storm motion.

The values of 0-6 km total shear U_s, 0-6 km bulk shear (U_{bs}), and 0-3 km storm-relative helicity (SRH) were calculated for each of the wind profile sources (Table 2). U_s ranged from 27.4 m s^{-1} for the 0000 UTC 5/31/99 CRP sounding to 48.9 m s^{-1} for the 0014 UTC KHGX VWP. U_s is greater than or equal to U_{bs} by definition, with a resulting neglection of hodograph curvature in the U_{bs} calculation. U_{bs} ranged from 5.7 m s^{-1} for the 1200 UTC 5/30/99 LCH RAOB, to 21.6 m s^{-1} for the 0000 UTC 5/31/99 CRP RAOB. SRH ranged from 15 m^2 s^2 for the 2300 UTC MAPS profile, to 220 m^2 s^2 for the 0014 KHGX VWP.

Overall, U_s is the most stable parameter in terms of proportionality between the largest to smallest values—roughly 100%. U_{bs} has a roughly 400% difference. SRH ranges an order of magnitude between largest and smallest, yet all but one are within 100%. These results agree with Markowski et al. (1998), Bunkers et al. (2000), and Weisman and Rotunno (2000), that U_s is a relatively consistent predictor of supercell potential (assuming initiation of deep moist convection).

Earlier points about the data sources are also evident. The 0014 UTC 5/31/99 KGHX VWP was the closest non-model data source to the near-storm environment, and more clearly indicated supercell potential than the other sources. The 2300 UTC 5/30/99 MAPS and RUC analysis soundings are derived in nearly the same manner, but small differences result in SRH differing by an order of magnitude between them—showing that data quality from model analyses can range from poor to good.

3.2 Central Texas – March 26, 2000

The Central Texas Supercells of March 26, 2000 were isolated left-moving (LM) and right-moving (RM) components of a split from an initial thunderstorm near the Granger (KGRK), TX, WSR-88D. The LM supercell produced 1.9 cm hail and wind damage to mobile homes and roofs. The RM supercell produced winds in excess of 22 m s^{-1}, wind damage to power lines, 3.2- to 6.4-cm hail, and a tornado in Seguin, TX.

Figure 5 shows the hodograph derived from the 0100 UTC 3/27/2000 MAPS analysis sounding closest to KGRK. Note the reasonable prediction of the motion of the LM (V_{LM}) and RM (V_{RM}) supercells from the method of Bunkers et al. (2000)—compared to the observed supercell motions (V_{obs}) from 2223 UTC 3/26/2000 (shortly after the supercell split) to 0100 UTC 3/27/2000. Figure 6 shows the LM and RM supercell locations at 2223 UTC and 0100 UTC. This latter case represents a situation where no traditional wind data were readily available, but model analyses provided good insight into the shear environment, resulting in a proper estimate of storm motions for the LM and RM supercells.

4. CONCLUSIONS AND RECOMMENDATIONS

Forecasting and monitoring supercell motion is critical to effective severe weather operations. Unfortunately, RAOBs are too spatially and temporally coarse to provide accurate wind profiles for estimating supercell motion most of the time. WPDN wind profiles, WSR-88D VWPs, ACARS, and model analysis and forecast profiles can serve as surrogates for improved estimates of the near-storm environment—resulting in better anticipation and forecasts of supercell potential and motion. However, each source has advantages and disadvantages that can render the acquired data invaluable or nearly useless.

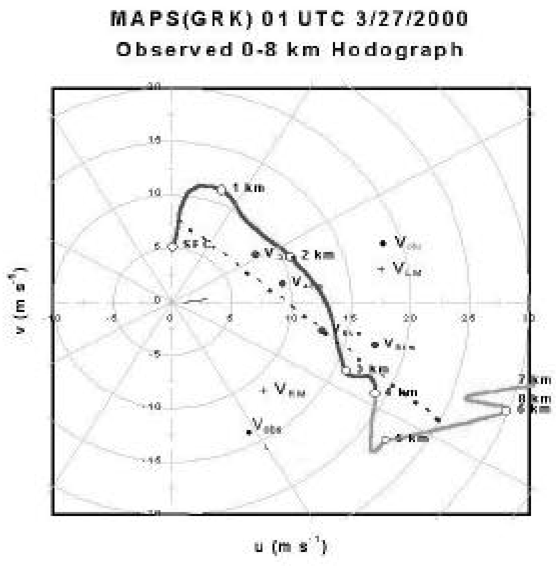

Fig. 5. Same as Fig. 1, except for the 0100 UTC 3/27/2000 MAPS (KGRK) hodograph, and V_{obs} for the right-moving and left-moving supercells.

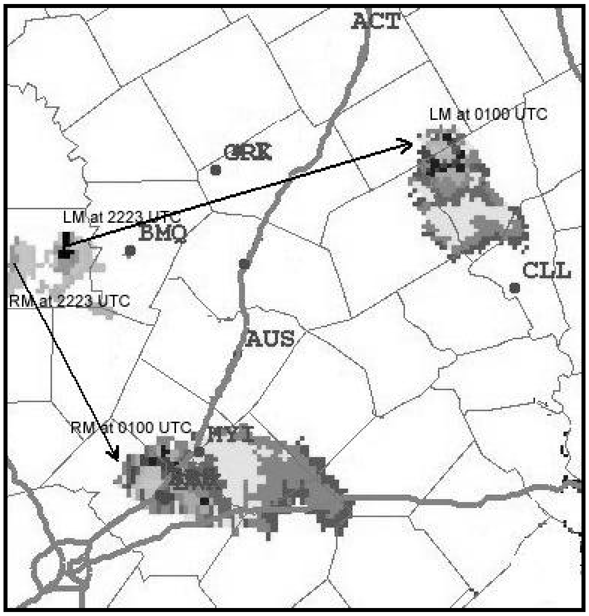

Fig. 6. Map of left-moving (LM) and right-moving (RM) storm locations and paths from 2223 UTC 3/26/2000 to 0100 UTC 3/27/2000. AUS is Austin, TX, GRK is Granger, TX, and CLL is College Station, TX.

The May 30, 1999, and March 26, 2000, supercells are examples of how varied data sources can provide differing levels of accuracy for anticipating supercells and forecasting their motion. In general, 0-6 km total shear (U_S) seemed the best predictor of supercell processes, while directly leading to the best prediction of supercell motion (based on the technique of Bunkers et al. 2000). The 0-6 km bulk shear (U_{bs}) and 0-3 km storm relative helicity (SRH) were again shown to vary widely—making them difficult to use on a consistent basis.

Despite the advances in supercell theory, observing systems, and operational modeling, the severe weather operations meteorologist is still faced with applying a preponderance of evidence in the selection of the most appropriate data source(s), especially for forecasts prior to storm development. Knowledge of the various data sources, parameter robustness, and preferred method for calculating storm motion will provide the best results for severe weather operations.

5. ACKNOWLEDGMENTS

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