JP3J.27 DYNAMICS OF MESOSCALE CONVECTIVE SYSTEMS OBSERVED WITH A UHF WIND PROFILER AND A POLARIMETRIC S-BAND WEATHER RADAR

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1. Introduction

The dynamics of mesoscale convective systems (MCSs) has been examined by numerous observations and numerical simulations. It is well-known that the characteristics of MCSs are complicated and classification is problematic due to their short lifetime of approximately a few hours as well as their spatial scale. Radar observations have good spatial-time resolution of approximately 250 m and a few minutes, respectively, which is enough to effectively examine MCSs.

The correlation between radar reflectivity (Z) and rainfall rate (R) is known to have accuracy problems due to several factors including attenuation, variation of hydrometeor distributions, etc. Therefore, recent studies have used differential reflectivity (Z_{DR}) and specific differential phase (K_{DP}) obtained by a dual-polarimetric radar for estimating the two parameters of the Gamma drop-size distribution (DSD), hence providing an improved rainrate estimate (e.g., Brandes 2002, Ryzhkov 2005). Given the estimated DSD from dual-polarimetric measurements, it is possible to estimate the terminal velocities of the hydrometeors.

A wind profiler can estimate the three-dimensional wind components from the radial velocities of a vertical-pointing beam and at least two oblique beams with fine time and range resolution. In the presence of precipitation, a UHF wind profiler primarily detects Rayleigh scattering from precipitation rather than Bragg scattering from clear-air turbulence. When hydrometeors are in the radar beam, the radial velocity of the vertical beam is determined by the terminal fall speed of the hydrometeors and the vertical air motion. Therefore, by using the terminal velocity calculated from the dual-polarimetric weather radar data and the radial velocity of the vertical beam of the profiler, it should be possible to estimate the vertical air motion in rainy conditions.

In the current study, we present complementary observations of MCSs observed in Central Oklahoma using a 404-MHz wind profiler with a Radio Acoustic Sounding System (RASS) and a dual-polarimetric S-band weather radar. The wind profiler is operated by National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL) and is located near Purcell, OK. The weather radar is KOUN operated by the NOAA National Severe Storms Laboratory (NSSL) in Norman, OK. The separation between the two sites is approximately 30 km (see Figure 1). The distance is large enough to be beyond contamination from the ground clutter but close enough to provide good spatial resolution. The vertical and temporal resolution of the profiler is exploited for the observations of MCSs in the non-precipitating regions (in particular at the leading edge) and compared to the storm structure observed with KOUN radar. We examine a case on May 13, 2005, when a classic squall line and associated gust front passed over KOUN and Purcell.

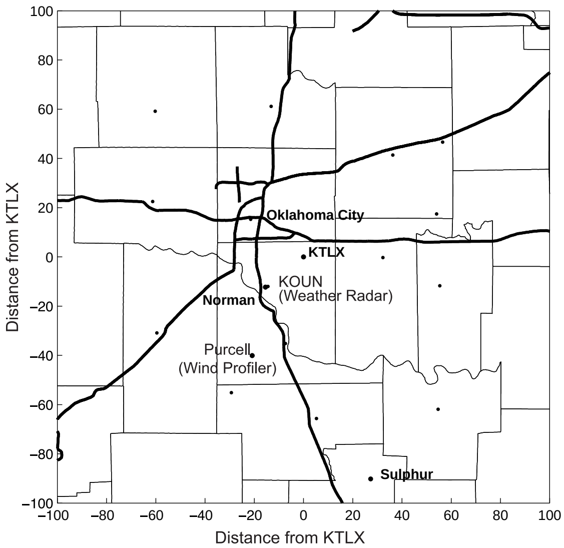

Figure 1. Map depicting location of the 404-MHz wind profiler and the KOUN weather radar.

2. Methodology

The KOUN radar performed surveillance scans with 14 elevation angles and 5-min updates on May 13, 2005. As the separation between the KOUN radar site and the profiler is approximately 30 km, the KOUN radar has a beamwidth of approximately 500 m and the lowest elevation angle samples are at 250 m above the FSL wind profiler. Drop size distributions were retrieved from Z and Z_{DR} at 6 height levels above the disdrometer site for the whole duration of the storm. We assume that DSD has a constrained Gamma form as suggested by Zhang et al. (2001) and Brandes et al. (2004) and is determined by two independent parameters that are estimated from Z and Z_{DR}. The details of DSD retrieval can be found in Ryzhkov and Zrnic (2005). The mean terminal velocity of raindrops was calculated from the retrieved raindrop spectrum. Estimates of differential reflectivity Z_{DR} used for the DSD retrieval were obtained after averaging raw values of Z_{DR} from 5 successive gates. Thus, effective horizontal resolution for the DSD and mean terminal

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velocity was about 1 km.

During routine operation, the FSL wind profiler provides profiles of the moments of the velocity spectrum every 6 minutes (Barth et al, 1994). As mentioned before, the Doppler velocity of the vertical beam (V_r) is associated with the vertical air motion (w) and the falling speed of hydrometeors (V_t). Given the terminal fall velocities retrieved from the polarimetric method, the vertical air motion can be calculated as shown in Figure 2.

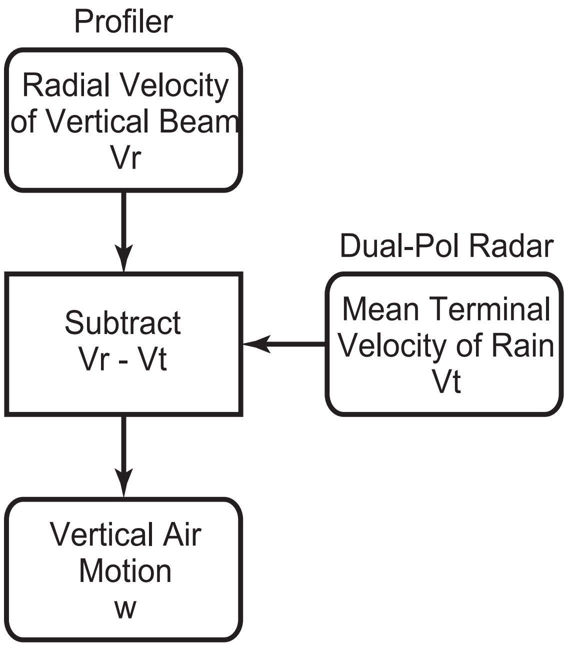

Figure 2. Flow chart for the calculation of the vertical air motion.

3. A Case Study: May 13, 2005

Here, we show the characteristics of a gust front and a squall line, which passed over the wind profiler at 0722 UTC (Figure 3). The gust front moved southeastward with the propagation speed of approximately 14.8 ms^{-1} calculated by the reflectivity data at 0.5° elevation. Large spectrum widths were found along the gust front observed with the WSR-88D KTLX radar (Figure 4), which could be due to the large winds and/or non-meteorological targets within the radar beam.

The wind profiler operated continuously both before and after the gust front passage. The MCS consisted of a gust front at 0722 UTC, deep convective clouds in the period between 0724 and 0748 UTC, and stratiform clouds after 0748 UTC (Figure 4). After the gust front passage, strong echo power was observed with the profiler (see Figure 5). In the stratiform region, the strong echoes were observed up to 6 km implying large hydrometeors. Moreover, relatively large spectrum widths were observed below 3 km (not shown), which was the approximate height of the freezing level. These results imply strong turbulence in this region.

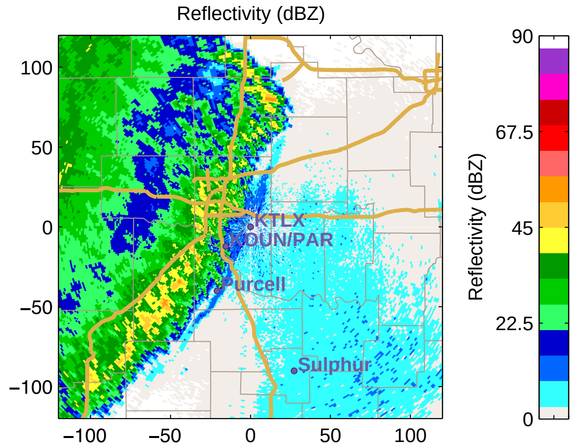

Figure 3. Reflectivity at 0.5°elevation observed with KTLX weather radar at 0722 UTC.

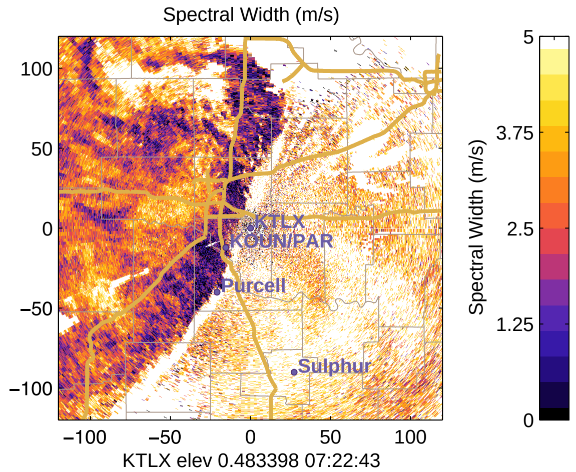

Figure 4. Same as Figure 3 but for spectrum width data.

The radial velocities of the vertical beam (V_r) observed with the wind profiler were interpolated linearly to fit the terminal velocity estimates. To estimate the vertical air motion in a rainy condition, the vertical velocities were adopted if their echo power was larger than 80 dB.

As mentioned before, the KOUN radar was operated with 14 elevations, and the horizontal distance between the KOUN radar and the wind profiler was approximately 30 km. Therefore, the height range, where the radar could estimate the mean terminal velocity (V_t), was between 0.22 and 2.68 km with a spacing of 0.5 km.

The vertical air motion was calculated using the method outlined in Figure 2. In the convective region, an updraft of 4 ms^{-1} was found, associated with the leading edge of the convective clouds. In the stratiform region after 0812 UTC, the average of the vertical air motion was upward with value between 0 and 2 ms^{-1} (Figure 9). Similar analysis of a squall line were conducted (e.g., May and Rajopadhyaya 1996, May and Keenan 2005), but an updraft in the stratiform region was not reported. The reason for the weak updraft in the stratiform region is not clear.

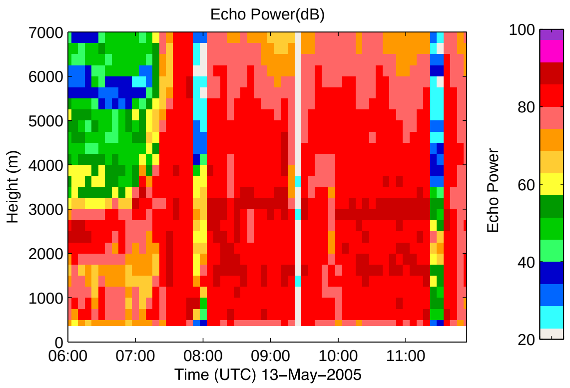

Figure 5. Time-height cross-section of echo power of the vertical beam of the profiler in the period between 0700 and 1200 UTC.

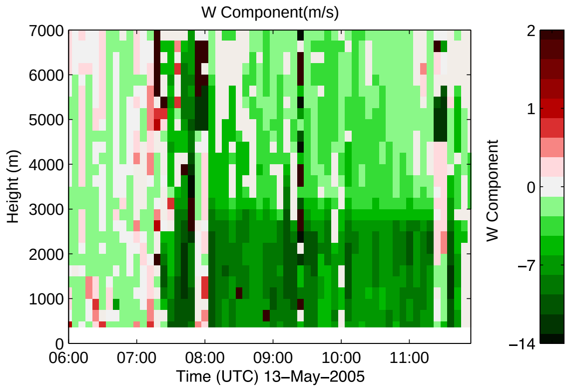

Figure 6. Same as Figure 5 but for vertical velocity of the vertical beam. Positive and negative indicate away from and towards the profiler, respectively.

4. Concluding Remarks

We attempt to estimate the vertical air motion in an MCS of strong convective and stratiform precipitating clouds. The vertical air motion was calculated from the height profiles of radial velocities from the vertical beam and the mean terminal velocities of hydrometeors. An updraft of 4 ms^{-1} was found at the leading edge of the convective clouds. In the stratiform region, the time average of the vertical air motion showed a weaker updraft.

These are preliminary results for the estimation of the vertical air motion in an MCS, and further discussion and investigation are necessary. The data observed with the FSL wind profilers are provided as only moments of echo power, radial Doppler velocity, and spectrum width, not the entire Doppler spectra. Future work will include the detailed spectral analysis of profiler data in order to determine any limitations of the proposed technique.

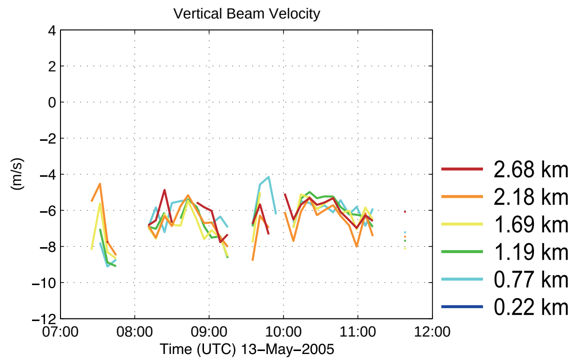

Figure 7. Radial velocity of the vertical beam (V_r) observed with the wind profiler in the period between 0700 and 1200 UTC. Positive and negative values indicate the velocities away from and towards the profiler, respectively.

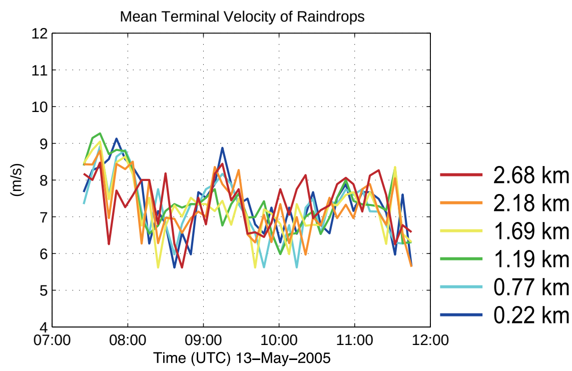

Figure 8. The mean terminal velocity (V_t) calculated from the KOUN radar. Positive value means the fallings of hydrometeors towards the ground.

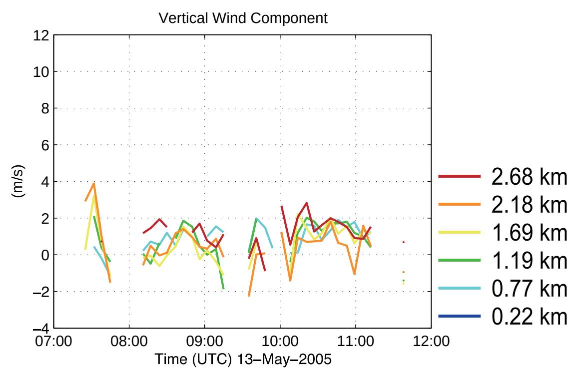

Figure 9. Vertical air motion (w) estimated using the technique in Figure 2.

Acknowledgments

The wind profilers are routinely operated by NOAA/FSL, and the KOUN weather radar is operated by NOAA/NSSL. The WSR-88D (KTLX) weather radar data are provided by NOAA/NWS.

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