3.6 A POTENTIALLY VALUABLE WSR-88D SEVERE STORM PRE-CURSOR SIGNATURE IN HIGHLY DYNAMIC, LOW CAPE, HIGH SHEAR ENVIRONMENTS

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1. INTRODUCTION

It is generally recognized that isolated supercellular storms account for the majority of strong tornadoes, thunderstorm wind-related damage, and loss of life in the United States (Moller et al., 1994). However, a high percentage of severe wind and tornado events that affect areas in and around Illinois are usually not associated with isolated supercell structures. Most of these severe events are produced by bow echoes, derechoes, multicell complexes, or supercells that are embedded in Quasi-Linear Convective Systems (QLCS). Unlike the first three severe weather producing systems mentioned, QLCS-embedded severe event producing supercells can often occur in environments that include relatively low convective available potential energy (CAPE) in which dynamic forcing is significant and shear is high. In the Midwest, these conditions are most common in the cool-season.

The mission of the National Weather Service (NWS) is the protection of life and property (NWS, 1999). To accomplish this mission an arsenal of technologies, conceptual models, training resources, workload models, and communication tools must be integrated successfully. As technology and our understanding of the atmosphere improve, additional tools join the armory available to the operational meteorologist. With advances in real-time WSR-88D data and temporal resolution available to the NWS warning team, along with enhancements in visualization afforded by the Advanced Weather Interactive Processing System (AWIPS) (MacDonald and Wakefield, 1996), NWS meteorologists can combine their knowledge of conceptual models with what they are observing through radar, satellite, and other remote sensing tools to produce a more accurate forecast of severe weather potential.

However, the collection of tools to access the potential for severe weather in cool-season QLCS is relatively limited given the research and training focus on more "traditional" severe weather environments. One tool that has begun to be utilized by the NWS office in Lincoln Illinois (KILX) has been a radar signature that has become more apparent with the availability of WSR-88D 8-bit data resolution in real-time (Barker and Miller, 2003). During several events over the 2004 through 2006 cool-seasons, a "reflectivity tag" or "reflectivity bulge" was observed moving quickly through a quasi-linear cluster of potentially severe storms. This feature generally moved more quickly than embedded cells within the line, and often appeared to be linked to a jet streak evident in both GOES 6.7 µm imagery and the National Profiler Network (NPN) (Chadwick, 1988). As these features moved past an embedded supercell with a persistent rotational couplet, a tornado or straight-line severe wind swath was occasionally produced shortly thereafter. The environments that appear to be most conducive for this interaction are highly dynamic, and contain low CAPE and relatively high shear.

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2. EXAMPLES

Occurrences of this signature can be observed in datasets of the November 6, 2005 Evansville Indiana Tornado, the November 15, 2005 Newton Illinois Tornado, and the Saybrook Illinois Microburst Event of March 13, 2006.

2.1 *Example of a Reflectivity Tag*

At 0739 GMT on November 6, 2005, an F3-rated tornado touched down and moved across southern portions of Evansville Indiana. This tornado produced 24 fatalities along its 66 km path (Storm Data, 2005). This event is shown as an example of a reflectivity tag signature. The pre-cursor environment of this tornado has been covered extensively by Wielgos and Spoden (2006) and others and will only be briefly discussed here. The most significant elements to this study include relatively low CAPE (886 Jkg^{-1}) and high 0-3 km environmental storm relative helicity (579 m^2s^{-2}) as indicated by a generated sounding at Evansville produced by the Local Analysis and Prediction System (LAPS) (Schultz, 1996) for 0700 GMT (not shown).

A long-lived supercell (LLSC) embedded in a QLCS tracked across southeast Missouri and southern Illinois at 26 ms^{-1} through the evening hours producing only sporadic reports of straight-line wind damage (Storm Data, 2005).

When WSR-88D 0.5° elevation reflectivity (Z) and velocity data from Paducah, Kentucky (KPAH) is viewed temporally, a reflectivity tag is evident moving northeast along the west edge of the QLCS. This tag can be

Figure 1a - KPAH 0.5° Z 0647 GMT Nov 6, 2005. LLSC represents location of Long-Lived Supercell.

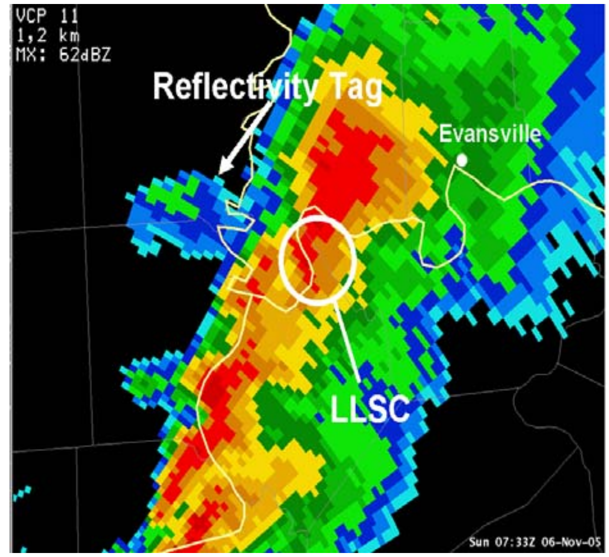

Figure 2a - Same as Fig 1a except for 733 GMT.

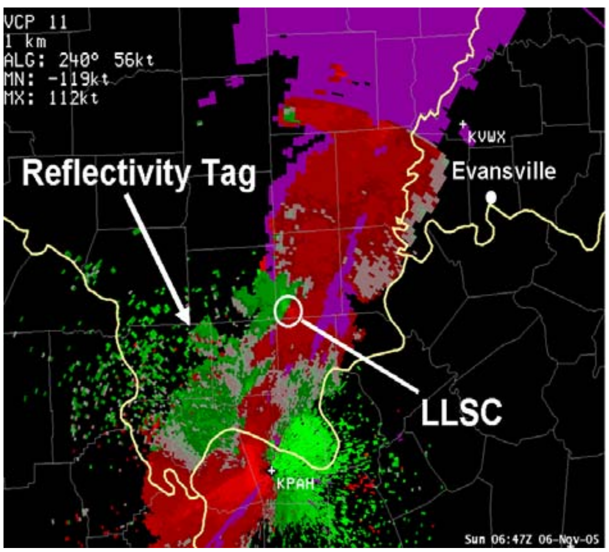

Figure 1b - Same as Fig 1a except SRM.

Figure 2b - Same as Fig 2a except for SRM.

viewed in the KPAH 0.5° Z and storm-relative velocity (SRM) data as it moves along the Ohio River at 0647 GMT, or 52 minutes prior to tornadogenesis (figures 1a and 1b). By 0733 GMT, or 6 minutes prior to tornadogenesis, the tag has caught up to the LLSC (figures 2a and 2b), and as tornadogenesis occurs, the tag moves past (figures 3a and 3b).

Several smaller tags with a wavelength of approximately 30 km are also evident, particularly when reflectivity images are rapidly looped. The process that produced these signatures interacted with the supercell and lead to conditions that made the storm-scale environment more conducive to the formation of the tornado.

2.2 *Example of a Reflectivity Bulge*

An example of a reflectivity bulge is demonstrated using the Newton, Illinois tornadic storm of November 15, 2005. Numerous tornado reports were received south and east of the QLCS in isolated supercells (Storm Data, 2005). Two F1-rated tornadoes occurred along a QLCS to the northwest of the area of isolated supercells. The longest track tornado was associated with an embedded supercell coincident with a reflectivity bulge moving up the QLCS (Storm Data, 2005). Indications of the bulge can be seen in 0.5° Z data from KILX at 2056 GMT southwest of Effingham Illinois (figure 4). As the bulge catches up to a long-lived rotating supercell embedded in the QLCS, rotation

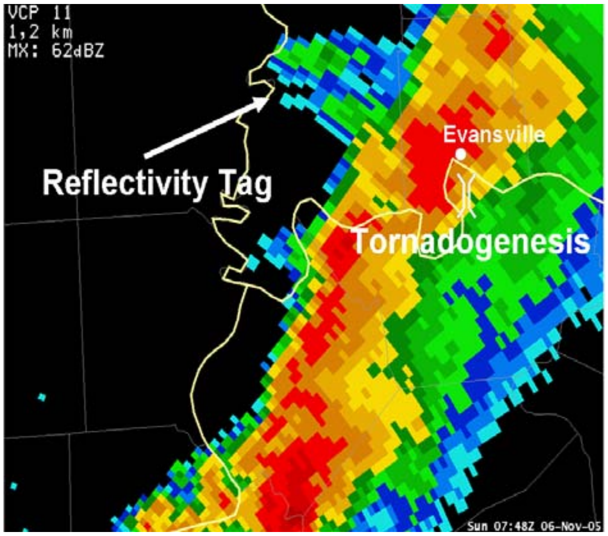

Figure 3a - Same as Fig 2a except for 0748 GMT.

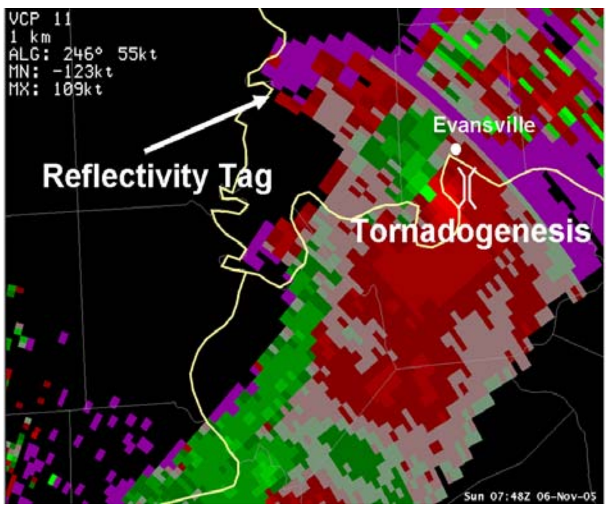

Figure 3b - Same as Fig 3a except for SRM.

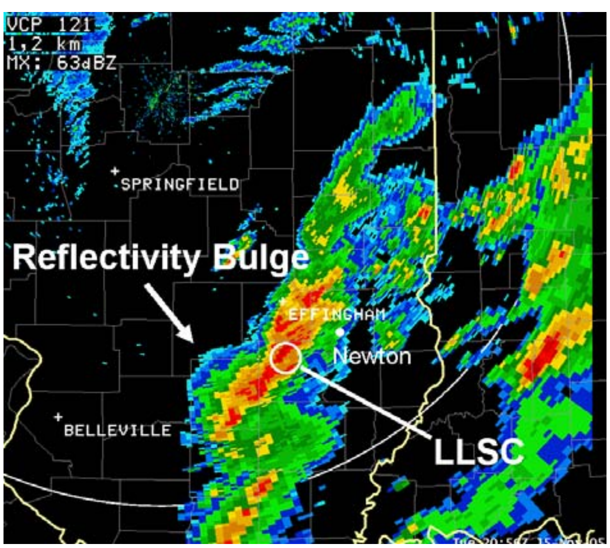

Figure 4 - KILX 0.5° Z 2056 GMT Nov 15, 2005.

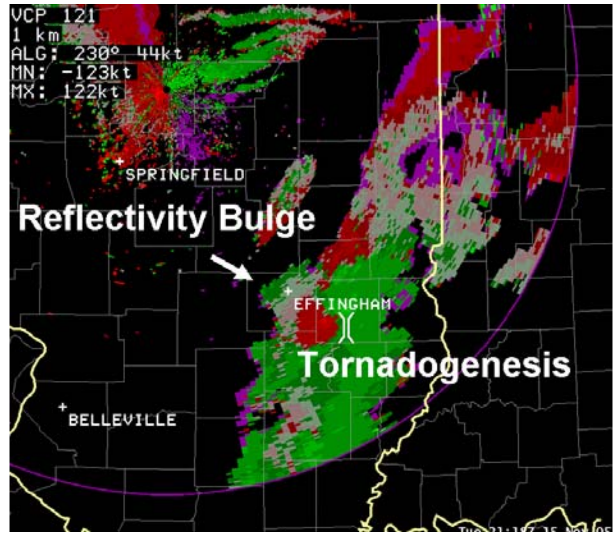

Figure 5 - KILX 0.5° SRM 2118 GMT Nov 15, 2005.

intensifies and contracts as indicated by 0.5° KILX SRM data for 2118 GMT (figure 5). An F1-rated tornado occurred with this cell at 2115 GMT passing just north of Newton Illinois during its 16 km path.

2.3 *Example of a Reflectivity Tag Protruding on the Downstream Side of a QLCS*

Another example of a reflectivity tag extending perpendicular to an eastward-moving QLCS occurred near Saybrook Illinois during the early morning hours of March 13, 2006. The previous evening was already noteworthy in central Illinois with two F2-rated tornadoes hitting the city of Springfield Illinois (Storm Data, 2006). One long-track tornado occurred with a continuous path length of 106 km. In all, nine tornadoes occurred across the area with isolated supercells that developed in a highly sheared environment. As the event evolved, a QLCS developed along a cold front that transversed the region in the wake of the tornado producing supercell. At 0838 GMT a microburst wind event collapsed a building in downtown Saybrook Illinois. Wind speeds were estimated by a NWS survey team to have reached 31 ms^{-1} (Storm Data, 2006).

The first sign of a reflectivity tag develops east of the line around 0811 GMT on the KILX 0.5° Z scan (figure 6). Although, the signature is similar to what one might expect from a storm-produced boundary, the pattern of regularly-spaced multiple tags with an approximate wavelength of 15 km suggests a different source mechanism.

By 0938 GMT, the 0.5° Z scan at KILX indicated that the most prominent tag was moving across the strongest cell in the QLCS as it is in the process of approaching Saybrook (figure 7). This image corresponds with the onset of the microburst that produced damage in Saybrook, one of only two reports of damage along this QLCS in north central Illinois (Storm Data, 2006) during this portion of the event.

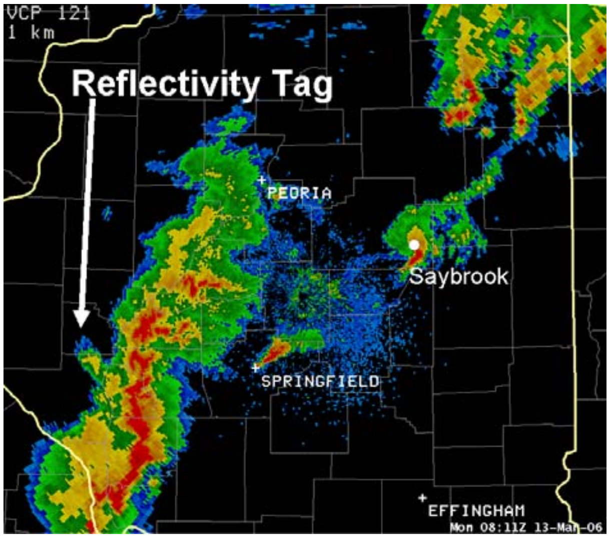

Figure 6 - KILX 0.5° Z 0811 GMT Mar 13, 2006.

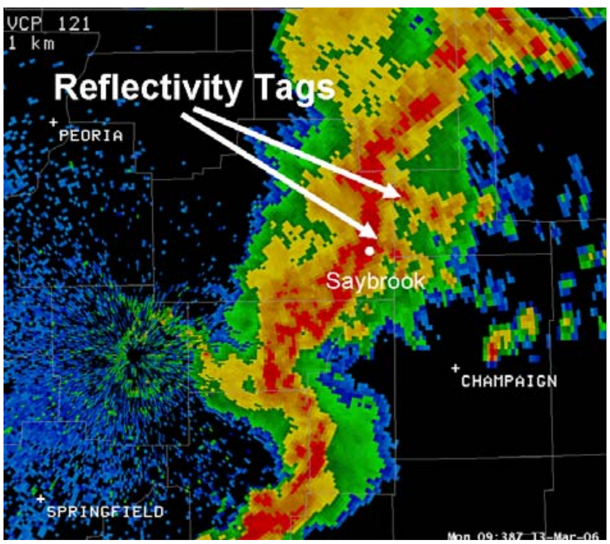

Figure 7 - Same as fig 6 except for 0938 GMT.

3. DISCUSSION

These three severe weather environments have many similarities: low to moderate CAPE, relatively high environmental shear, and the potential interaction of a QLCS with a significant jet streak. In addition, they occurred with a weak stable layer in place as indicated by the LAPS analysis software.

With regards to the Evansville case, GOES 6.7 µm imagery and NPN data taken at 0700 GMT indicated a jet streak approaching the QLCS (figure 8). The Velocity Azimuth Display (VAD) Wind Profile (Crum and Alberty, 1993) from the Evansville WSR-88D (KVWX) shows an increase in environmental winds at 7.6 km (25 Kft) above sea level from 34 ms^{-1} (65 kts) to 52 ms^{-1} (100 kts) between 0707 GMT and 0804 GMT (figure 9). This is indicative of a rapid increase in divergence in the upper portions of the storms leading to a resultant increase in upward vertical velocity. This enhancement in the updraft may have potentially lifted the weak stable layer destabilizing the column and leading to a change in the storm mode from elevated convection to one that rapidly became surface-based.

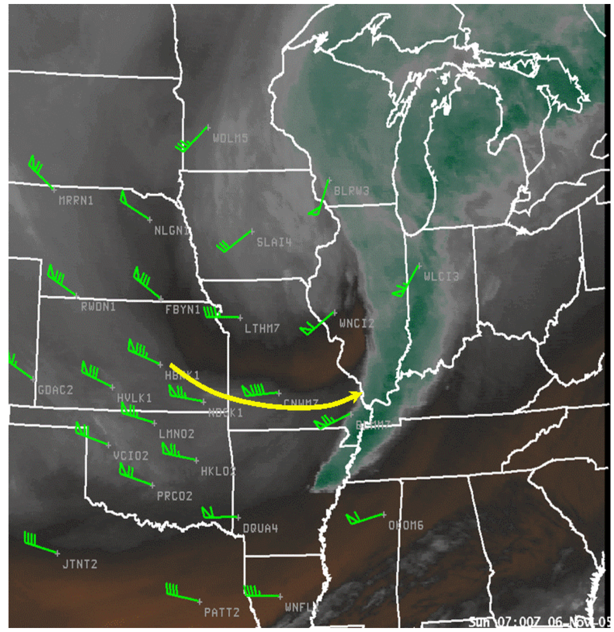

Figure 8 - GOES 6.7 um image and 400 hPa NPN Winds 0700 GMT Nov 6, 2005.

Similar increases in winds in the upper portions of the storm environment are indicated in the two other situations summarized above.

The signatures discussed may be physical markers for this process of enhanced storm exhaust and increased vertical velocity. One possible mechanism leading to the development of the wave-like nature of these signatures is gravity wave-convective storm interaction. Although many studies (e.g. Jewett et al., 2003, Koch and Saleeby, 2001; Stobie et al., 1983) have highlighted this interaction, it is only recently that temporal, spatial, and data display resolution in WSR-88D and satellite imagery have reached the point where evidence of these waves can be identified in real-time, and used as a potential input into operational warning decisions. As the waves move close to the KPAH radar, 0.5° SRM data from 0632 GMT shows an alternating convergence-divergence pattern (figure 10) similar to conceptual models as described by Koch et al. (1993) (figure 11). Coleman and Knupp (2006) provided a more complete discussion of the processes involved with the interactions of gravity waves with convective storms.

Further clues to the potential for small wavelength atmospheric wave formation can be noted northeast of Springfield in figure 4 in the form of a short wavelength wave packet moving north.

4. SUMMARY

Although there remains some uncertainty as to the cause of these reflectivity tag or bulge signatures, they are clues to a changing storm environment. The

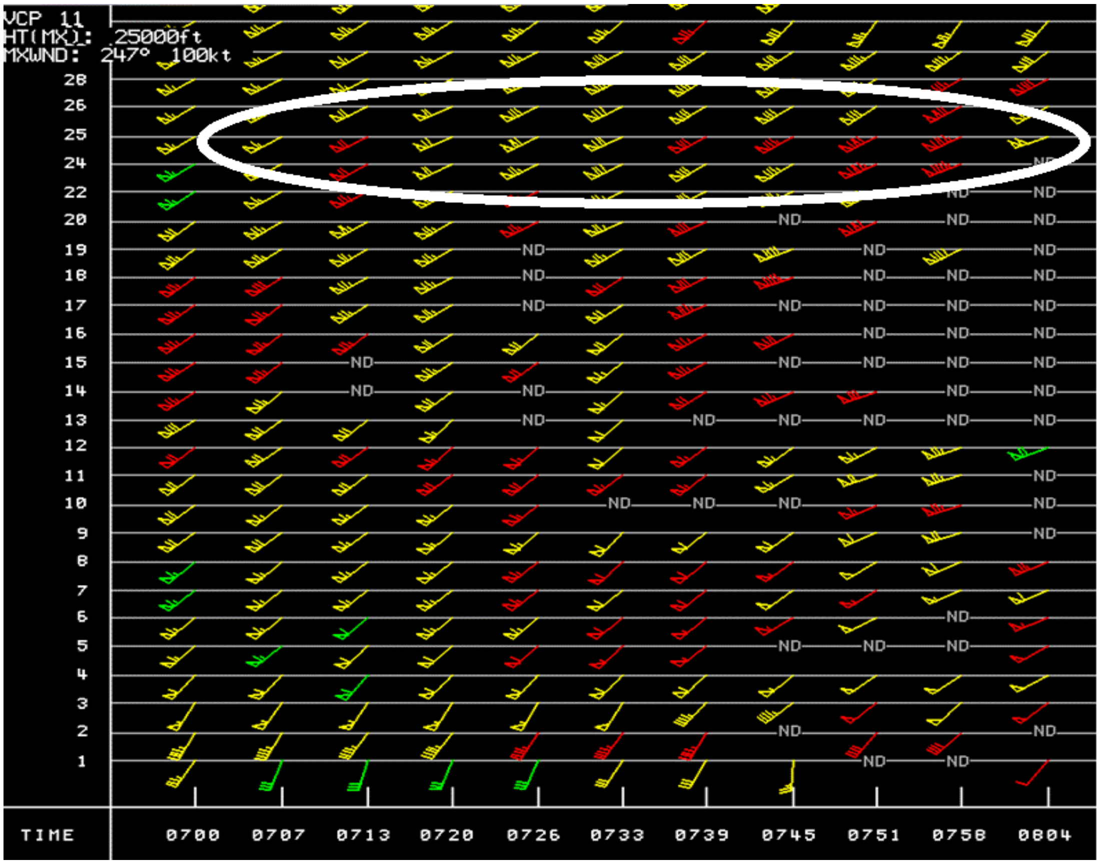

Figure 9 – KVWX WSR-88D VAD Wind Profile 0700-0804 GMT Nov 6, 2005.

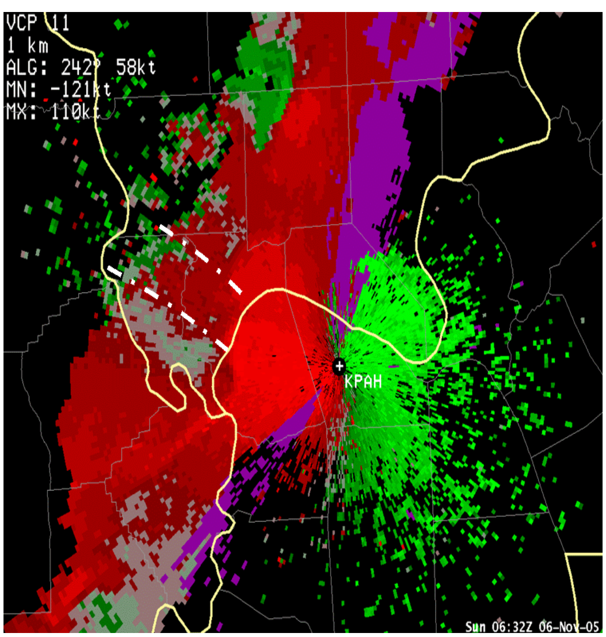

Figure 10 - KPAH 0.5° SRM 0632 GMT Nov 6, 2005.

realization of changes in the environment by operational meteorologists is critical to maintaining situational awareness during an evolving event (Andra et al, 2002; Barker et al, 2005).

Obviously, much more work needs to be done in identifying the cause and utility of the reflectivity tag and reflectivity bulge signatures. Future work includes expanding the dataset spatially and temporally. In addition to the cases mentioned above, two additional events (Nov. 1, 2004, Jan. 2, 2006) have been identified as having similar environments and radar signatures during the past two cool-seasons in central and southeast Illinois and will be examined. Further investigation into the underlying processes that are involved will also be critical for assessing the utility of this signature.

It is hoped that the recognition of these features through the use of rapid looping and detailed meso-scale analysis may provide operational meteorologists with another valuable tool in the forecasting of severe local storms in these challenging environments.

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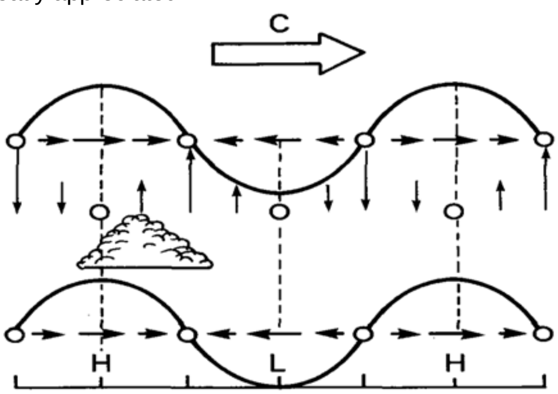

Figure 11 - Schematic Illustration of the height variation in the phase relations between the horizontal wind component in the direction of wave propagation and the wave-induced vertical motions for a gravity wave with no vertical tilt, which is propagating to the right with phase speed C. From Koch et al. (1993)

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