

Chapter 6: Conclusions

6.1 Hydrometeor characteristics observed

In all four cases studied, a deep layer of radial velocity convergence aloft was noted prior to the first radar indication of a microburst. In the three STEPS cases, in northeastern Colorado and northwestern Kansas, an initially elevated core of high reflectivity factor (Z) descended to the surface in conjunction with the microburst impact. The PRECIP98 case in Florida did not exhibit large Z values aloft until nearly the time of the microburst impact.

A differential reflectivity (Z_{DR}) "hole" was present in every case, consistent with the findings in WB88. However the characteristics of the hole varied from case to case. In the 23 June 2000 STEPS case, the hole appeared on RHI scans as small and well-defined near the strongest low-level radial divergence signature, and was wider and less defined along the fringes. The development of the hole in this case was preceded by a Z_{DR} "trough" aloft, as viewed in RHI cross section. In the 11 June 2000 STEPS case the Z_{DR} hole began with large diameter and contracted as the storm's mass converged into a column above. In the 22 June 2000 STEPS case, the most severe microburst signature observed among the four cases, the Z_{DR} hole suddenly appeared and rapidly expanded in diameter over time. Finally, in the 13 August 1998 PRECIP98 case, the Z_{DR} trough was entirely aloft. The presence of low Z_{DR} values, along with high Z values, near the microburst column suggests some hail is contained within the column. However, because Z_{DR} is biased toward more reflective scatterers, it cannot be known whether any rain is also present.

A local maximum in specific differential phase shift (K_{DP}) was also found in all four cases, typically near the base of the Z_{DR} trough or coincident with the Z_{DR} hole at

low levels. Since K_{DP} is immune to the presence of isotropic scatterers, and is not reflectivity weighted, this suggests that water drops are indeed present with the hail. The maximum value of K_{DP} appears to be relative to the diameter of the Z_{DR} hole or trough. There are two possibilities to explain this observation: First, the center of the hole or trough may be composed mostly of hail, which has isotropic bulk fall orientation, so the differential phase shift between the orthogonally-oriented radar pulses is small. The other possibility is that while a Z_{DR} column may contain a large amount of water content in the horizontal, the narrow nature of this feature results in a rapid spatial change in differential phase shift that is smoothed out in the range derivative calculation of K_{DP} . This may have resulted in the K_{DP} maximum being displaced from the Z_{DR} minimum at low levels in the 23 June 2000 STEPS case. Such an offset, however, was not evident in the other cases considered.

In all cases, the co-polar correlation coefficient ($\rho_{HV}(0)$) decreased downward in the downdraft column below the melting level. This is not surprising, as many studies and simulations suggest decorrelation occurs as increasingly diverse hydrometeor types are encountered. This PR variable can be used to confirm the presence of a rain, hail mixture when high Z , low Z_{DR} , and high K_{DP} values coincide. The relative changes in $\rho_{HV}(0)$ were too small, however, to easily detect the actual location of the microburst column.

These PR characteristics are consistent with the findings in BZ90. Melting hailstones in fall first exhibit increasingly large Z , low Z_{DR} , low K_{DP} , and high $\rho_{HV}(0)$ values. These PR variables are consistent with the R84 finding that hailstones form a water coat but do not form a water torus or shed drops until they have converted 20% of their mass to water. Below this first layer, a layer of PR characteristics exhibiting a rapid

rise in K_{DP} , drop in $\rho_{HV}(0)$, very high Z , and gradual rise in Z_{DR} is found. This is also explained by the R84 melting simulations. A water torus forms and numerous drops are shed during this stage of melting, yielding a rapid increase in water content in the horizontal and a rapid jump in K_{DP} . However, large diameter hailstones with bulk isotropic fall orientation are still present, keeping Z_{DR} small. The rapid increase in hydrometeor diversity causes $\rho_{HV}(0)$ to decrease. Finally, a third layer, closest to the ground, is marked by downward decreases in Z and K_{DP} , and downward increases in Z_{DR} and $\rho_{HV}(0)$. In this layer, the hail melts completely and a transition to typical rain signatures is found in the PR presentation. The addition of downward rushing air in a column of melting hail will cause these layers to become unstratified, into a funnel shape centered on the downdraft. Therefore, a PPI radar image through a microburst column driven by hail in melting layer 2 will exhibit a local minimum in Z_{DR} and local maximum in K_{DP} .

The ambient environment also impacts the radar signatures and associated microburst. The much higher melting level in the 13 August 1998 PRECIP98 case than in the three STEPS cases meant the Z_{DR} trough and K_{DP} maximum occurred entirely aloft. The 13 August 1998 microburst was still able to survive compressional warming and entrainment of environmental air during its descent because of the high ambient relative humidity in cloud and below cloud base, consistent with S87. The boundary layer was much drier in the three STEPS cases, and as predicted in S87, the melting occurred in a deeper layer, as shown by deeper melting PR signature layers. This allowed the strong downward acceleration due to diabatic cooling to occur nearer the ground, overwhelming the negative impacts of compressional warming and dry ambient air.

6.2 Operational implications

It is clear that all available information, including conventional radar signatures, environmental information, and all PR variables should be used in unison. The documented signatures may occur near the surface or aloft, so knowledge of the sustainability of a downdraft initiated aloft must be gathered as revealed by environmental data.

In cases where the signatures occur aloft, such as in the 13 August 1998 PRECIP98 case in Florida, some lead time before microburst impact may be possible. In events such as the three STEPS cases, where the cooling occurs close to the ground, more conventional radar signatures, such as an initially elevated reflectivity core and radial convergence aloft, may provide more lead time.

6.3 Future work

More downburst cases must be observed with PR before any meaningful statistics or thresholds can be offered. This includes a variety of environmental temperature lapse rates and relative humidities. This also includes "dry" microbursts, which are often not associated with melting hail, but with evaporating rain drops (Srivastava 1985) or sublimating ice particles. Such dry microbursts will certainly have different PR signatures.

In addition "null" cases must be considered. These should incorporate both cases where microbursts occurred but these signatures were not present, and cases where similar signatures cannot be associated with microbursts.

Although these results are preliminary and based on a small number of cases, it is clear that in these cases, melting hail is present within the microburst column. It is

generally accepted that melting hail, along with condensate loading, is a major contributor to wet microburst development and strength. S87 strengthened this concept with a numerical model, which showed diabatic cooling from melting hail is a dominant contributor. The PR observations in these cases suggest the hail melting process in wet microbursts may now be directly observable.