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SOME INTERIOR OBSERVATIONS OF SOUTHEASTERN MONTANA HAILSTORMS

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Introduction

As part of the 1981 Cooperative Convective Precipitation Experiment (CCOPE), several hailstorms in southeast Montana were penetrated at about the 6 km level by armored T-28 aircraft. Measurements of draft sizes and speeds, cloud liquid water concentrations (LWC), turbulence, and hail were obtained for both updraft and downdraft regions. Musil et al., presented their findings in the article "Some Interior Observations of Southeastern Montana Hailstorms" which was published in the December 1991 issue of the *Journal of Applied Meteorology*. The following are some of their more important findings.

Draft Sizes and Speeds

Updrafts were found to be more common than downdrafts. This contrasts with a study of Colorado storms (Musil et al., 1977) and Alabama storms (Musil and Smith, 1989). The authors gave evidence that the difference between the Colorado storms and the Montana storms may have been due to different methods employed by the two studies in determining vertical velocities. They speculate that the difference between Montana and Alabama results may have been due to "fundamental differences in the cloud and precipitation processes."

In the Montana study, updrafts tended to have greater horizontal extent than downdrafts. The average updraft width was 3 km while the average downdraft width was 2 km. This is in rough agreement with results from the above-mentioned Colorado study. Updrafts as wide as 15 km and downdrafts more than 8 km wide were observed in the Montana study.

Draft Velocities

Updrafts were found to be slightly stronger than downdrafts. Median speeds for updrafts and downdrafts were about 5 m sec^{-1} and 4.5 m sec^{-1}. The study found some correlation between updraft strength and updraft size. On the other hand, there was little relationship between downdraft size and speed.

Cloud Water

Most LWC observations were substantially below adiabatic, typically less than 25 percent of adiabatic values. This compares favorably with observations in the southeastern United States (Musil and Smith, 1989). Values were near adiabatic only in the cores of a couple of very strong updrafts. Interestingly, downdrafts often contained substantial amounts of cloud liquid. In fact, the ratio of observed to adiabatic LWC values was similar for both updrafts and downdrafts.

Whereas there was a correlation between maximum cloud LWC in the updrafts and maximum updraft speed, there was no corresponding correlation for downdrafts. The authors gave some evidence that the reason for the relatively low LWC values in the updrafts may have been due to dry air entrainment rather than depletion of LWC.

Turbulence

The updrafts tended to be more turbulent than the downdrafts. Results indicated that more intense turbulence is associated with larger storms because higher draft velocities tend to be found in larger storms. The most intense turbulence was randomly positioned with respect to the updraft regions.

Hail

Maximum hailstone size ranged from 5 mm to 50 mm. Hail was usually found in regions of moderate updraft and usually extended into the associated downdraft, downstream. The upstream parts of the same updrafts tended to be hail free. However the lone supercell storm in this study exhibited reverse behavior in that the greatest amount of hail was found to the west of the Weak Echo Region (WER).

Larger hailstones tended to be found in storms with stronger updrafts suggesting that strong updrafts are probably necessary to sustain the growth of large hailstones. The largest hailstones occurred with the storms that had the widest updraft regions. This supports the finding of Nelson (1983), who demonstrated that a critical factor for hail growth is a broad region of moderate updraft. This allows more time for the development of hail.

Interestingly, this study found a better correlation between hail concentration or hail maximum size and reflectivity than with either hail parameter and the reflectivity gradient. This contradicts other studies (e.g. Sands, 1976) which found that hail was most frequently found in areas of strong reflectivity gradient.

Finally, the results concerning LWC have serious implications for some computer models of hailstone growth. These models typically treat updrafts as containing 100 percent adiabatic LWC and downdrafts as having no cloud liquid. Observations from this field study indicated that updrafts usually contain much less than 100 percent adiabatic LWC while downdrafts were not free of cloud water.

Although the study did not give any empirical rules on how to forecast hailstorms in southeast Montana, it did give some important characteristics of these storms. Observations such as these will hopefully be incorporated into suitably designed computer models in order to advance the understanding of hail growth mechanisms.

References

Musil, D. J., and P. L. Smith, 1989: Interior characteristics at mid-levels of thunderstorms in the southeastern United States. *Atmos. Res.*, 24, 149-167.

Musil, D. J., P. L. Smith, J. R. Miller, Jr., J. H. Killinger, and J. L. Halvorsen, 1977: Characteristics of vertical velocities observed in T-28 penetrations of hailstorms. Preprints, Sixth Conf. Inadvertent Weather Modification, Champaign-Urbana, IL, Amer. Meteor. Soc., 166-169.

Nelson, S. P., 1983: The influence of storm flow structure on hail growth. *J. Atmos. Sci.*, 40, 1965-1983.

Sand, W. R., 1976: Observations in hailstorms using the T-28 aircraft system. *J. Appl. Meteor.*, 15, 641-650.