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DUAL-DOPPLER AND AIRBORNE MICROPHYSICAL OBSERVATIONS IN THE STRATIFORM REGION OF THE 10-11 JUNE MCS OVER KANSAS DURING PRE-STORM

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1. INTRODUCTION

During May-June 1985 the PRE-STORM (Preliminary Regional Experiment for the Stormscale Operational and Research Meteorology Program-Central Phase) Project was conducted, focusing on Mesoscale Convective Systems (MCS's) as they passed over the Great Plains. The particular case we study herein is the 10-11 June 1985 storm. This storm was characterized by a line of convection trailed by a broad region (~100 km) of stratiform rain. We examine the kinematic and microphysical structure of the trailing stratiform region through dual-Doppler and airborne observations.

2. DUAL-DOPPLER OBSERVATIONS

We discuss the dual-Doppler analysis at 0345 Z on 11 June. At this time the storm was in it's mature phase, shortly after which the convective region weakened. This time corresponds to in-situ airborne observations of particular interest. The dual-Doppler data were obtained from the network located in Kansas, consisting of the NCAR (National Center for Atmospheric Research) CP-3 and CP-4 5 cm radars. Overview details of the techniques used in the dual-Doppler analysis are given in Biggerstaff et al. (this volume). The horizontal flow structure relative to the storm is shown in Figs. 1a-c. The bulk of the convective region had moved out of the domain at this time. The low-level flow (Fig. 1a) was parallel to the convective line, especially in the transition zone and the leading portion of heaviest stratiform precipitation (defined by x=-30 to x=30 km). Strong outflow at the rear of the stratiform precipitation zone was present. This outflow is fed by air entering the rear of the system at upper levels and subsiding in a strong mesoscale downdraft. At 3.9 km (Fig. 1b) the flow was rear-to-front, but again became parallel to the convective line in the transition region. Rear-to-front flow has been previously identified by Smull and Houze (1985). At upper levels (Fig. 1c) the flow had a strong front-to-rear component. This flow transports ice produced in the convective region into the stratiform region which plays an important role in the water budget of the stratiform region (Rutledge and Houze, 1987).

Mean vertical cross-sections for the region bounded by y=-30 to y=30 km are shown in Fig. 2. The reflectivity field (Fig. 2a) is characteristic of stratiform precipitation (note distinct bright band structure). The transition zone is seen as a low-level depression in reflectivity (x=30 to x=55 km). The relative flow perpendicular to the convective line (Fig. 2b) clearly shows the rear inflow layer (shaded). Front-to-rear flow (right to left) above the rear inflow layer is deep and rather uniform with height. The mean vertical velocity (Fig. 2c) shows deep mesoscale lifting throughout the cross-section with speeds to 50 cm/s, and a well-defined mesoscale downdraft of comparable magnitude. The mesoscale downdraft is broad, interrupted only near x=0 by weak upward motion. The mesoscale downdraft gives way to deeper and stronger subsidence in the transition zone resulting from evaporatively driven downdrafts at mid- to low-levels and by the merger of outlows from the upper parts of convective cells with environmental flow near the tropopause (see Biggerstaff et al. this volume). The stronger subsidence in this region may be partly responsible for the observed precipitation minimum in the transition zone. The top of the mesoscale downdraft is roughly associated with the top of the rear inflow jet, at least for x<0 km, suggesting a close link between the penetration of dry air into the rear of the storm and mesoscale subsidence.

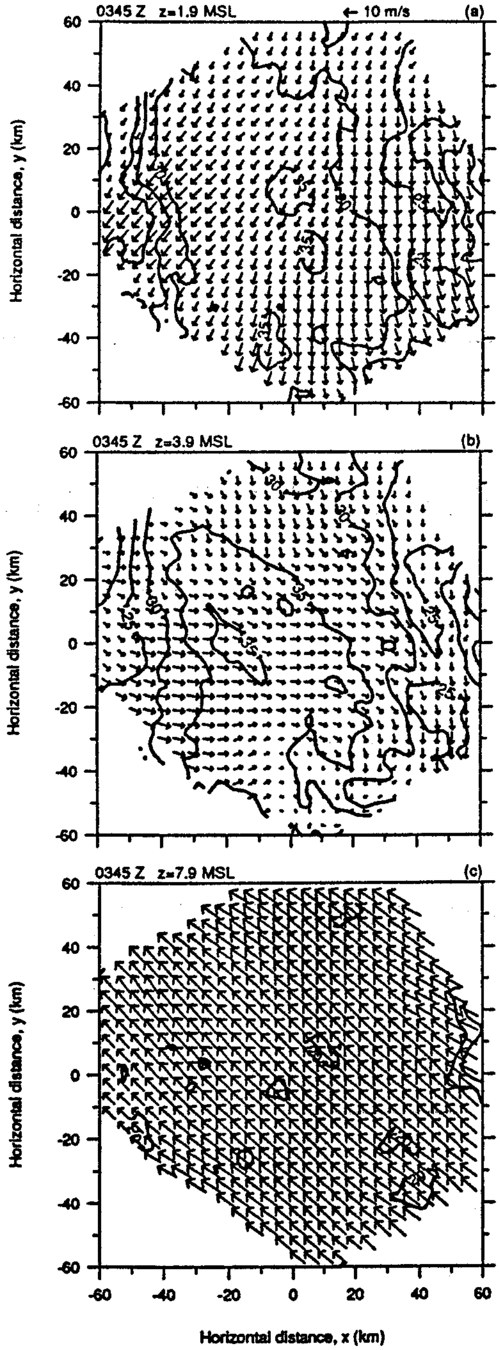

Fig. 1. Relative flow and reflectivity (dBZ) for 0345Z on 11 June 1985. a) z=1.9 km MSL. b) z=3.9 km MSL. c) z=7.9 km MSL.

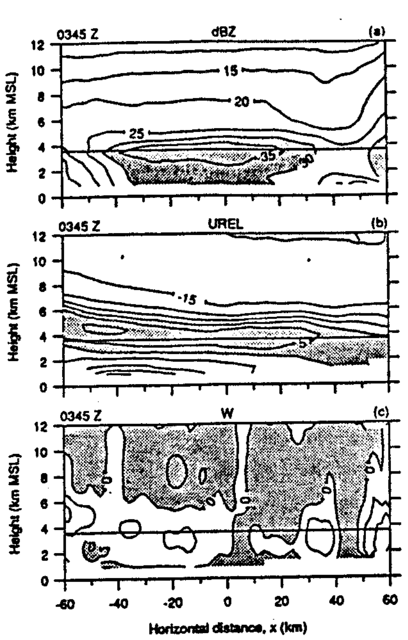

Fig. 2. Mean cross-sections for the region bounded by y=-30 to y=30 km. a) Reflectivity, >30 dBZ shaded. b) Reflective flow perpendicular to convective line. Shading denotes flow from left-to-right. Contour interval is 5 m/s. c) Vertical velocity. Shading denotes upward motion. Contour interval is 50 cm/s. The melting level is denoted by the horizontal line at 3.6 km.

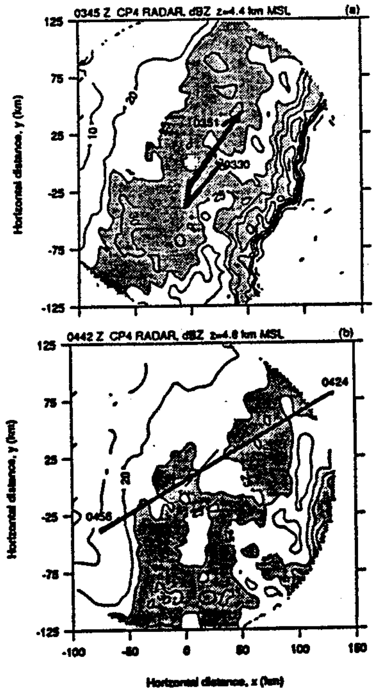

Fig. 3. Reflectivity and aircraft flight tracks. a) dBZ for 0345Z at 4.4 km MSL; NOAA 43 flight track. b) dBZ for 0442Z at 4.8 km MSL; NOAA 42 flight track. Reflectivities > 25 dBZ are shaded.

3. AIRBORNE OBSERVATIONS

Both NOAA (National Oceanic and Atmospheric Administration) WP-3D aircraft obtained in-situ microphysical observations in the trailing stratiform region. From these data mixing ratios for ice were then derived. Particle sizes and habits were determined using the 2-D PMS cloud and precipitation probes. The data collection is summarized by discussing ice water contents and particle habits along the aircraft flight tracks. Two periods of observations are discussed: 0330 to 0351 Z by NOAA 43, consisting of an ascending path from 4.0 to 5.4 km situated along the leading edge of the band of most intense stratiform rain (Fig. 3a); 0424 to 0456 Z by NOAA 42 consisting of a level pass through the stratiform region at 4.8 km MSL (Fig. 3b). The microphysical observations are summarized in Tables 1 and 2.

The observations from NOAA 43 near the transition zone indicate a sharp increase in IWC with height. The marked increase at 0339 Z, with nearly a doubling of the IWC, is associated with the aircraft's ascent through the top of the rear inflow layer, or into the ice-laden front-to-rear flow (Fig. 2b). Particle types were predominantly aggregates of unidentifiable particles, consistent with ice particles produced in convective cells. The increase in IWC with height may also be a result of intense sublimation in the transition zone caused by strong downdrafts (see Fig. 2c). The microphysical results for NOAA 42 indicate a fairly uniform IWC with the exception of the end of the leg, at which point NOAA 42 passed through the back edge of the intense stratiform precipitation, below the base of the deep stratiform cloud. Particle types were predominantly aggregates of dendrites. Evidently the dendrites were produced above this level (near -14 °C, z=6 km) then drifted downward and aggregated at lower levels. This indicates particle nucleation and growth in the mesoscale updraft. The presence of needles also is an indicator of nucleation in the mesoscale updraft, immediately above flight level. Particle observations also indicated riming growth may have been present. Peak updrafts approached 1 m/s in the stratiform region, which would have generated supercooled water.

Table 1. Ice water contents and particle habits for 0330-0351Z from NOAA 43.

Time (Z)	T (°C)	IWC(g/m^3)	HABITS
0330	-1.0	0.2	Giant* aggregates
0333	-0.3	0.5	"
0336	-0.7	0.6	Large* aggregates
0339	-2.3	1.3	"
0342	-3.6	1.3	Small* aggregates
0345	-3.5	1.9	Small aggregates, needles
0348	-5.1	1.7	"
0351	-6.8	1.4	"

*Giant D > 1 cm; large D > 5 mm, small D < 5 mm.

Table 2. Ice water contents and particle habits for 0424-0456Z from NOAA 42.

Time (Z)	T (°C)	IWC(g/m^3)	HABITS
0424	-4.4	0.89	Aggregates of dendrites, needles
0428	-4.2	1.34	"
0431	-3.6	1.41	Some needles, aggregates
0434	-3.8	1.81	Aggregates, lightly rimed
0437	-3.4	1.25	"
0440	-3.5	1.63	"
0443	-3.2	1.23	Aggregates of dendrites
0446	-2.7	1.37	"
0449	-2.5	1.24	Some dendrites, possible riming
0452	-3.4	0.10	Aggregates, some dendrites
0456	-3.8	0.01	

4. CONCLUSIONS

Dual-Doppler observations revealed three distinct flows in this storm: front-to-rear flow at low levels, strong rear-to-front flow at mid-levels, and deep front-to-rear flow aloft. The rear inflow was responsible for intense sublimation and evaporation at low levels, which resulted in a strong mesoscale downdraft. The front-to-rear flow evidently transported ice particles into the trailing region. Particle observations in the stratiform region indicated in-situ production of ice particles by the mesoscale updraft.

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