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AIRBORNE DOPPLER RADAR AND CLOUD MICROPHYSICAL MEASUREMENTS IN HURRICANE NORBERT

Robert A. Houze, Jr.
Department of Atmospheric Sciences
University of Washington
Seattle, Washington 98195

and

Frank D. Marks, Jr., Robert A. Black,
Paul T. Willis and John F. Gamache
Hurricane Research Division
NOAA/AOML
Miami, Florida 33149

1. INTRODUCTION

On 22, 23 and 24 September 1984, two NOAA WP-3D aircraft flew coordinated research missions in the inner-core region of Hurricane Norbert, which was located over the Pacific Ocean, southwest of the southern portion of Baja California. This paper describes preliminary results of the data collected on 24 September.

On this day, the storm displayed a well defined eye and was moving northwestward at 5 m/s. The central pressure averaged 955 mb at the surface and the maximum wind at 3 km altitude was 50-55 m/s in all quadrants of the storm. The horizontal radar reflectivity distribution (Fig. 1) exhibited an asymmetric eyewall, with the maximum-intensity convective echo to the southwest of the center of the storm.

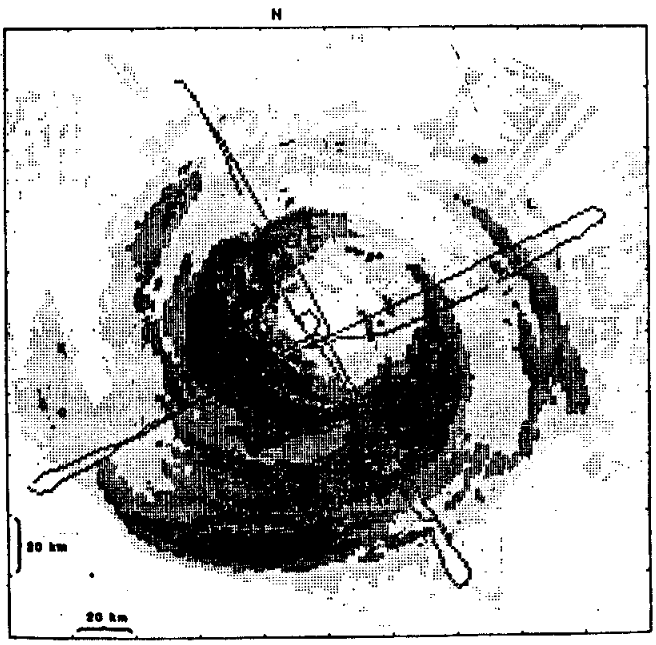

Fig. 1. Time composite of the horizontal distribution of reflectivity in Hurricane Norbert for 0215-0402 GMT 25 September 1984 from 3 km altitude. The reflectivity contours are for 28, 31, 34, 38, and 42 dBZ. The aircraft flight track is indicated by the solid line and tick marks are spaced 20 km apart. The origin of the coordinate system is located at the storm center, and the aircraft positions have been plotted relative to the storm center. Coordinates are east-west distance (X) and north-south distance (Y) in km from the storm center.

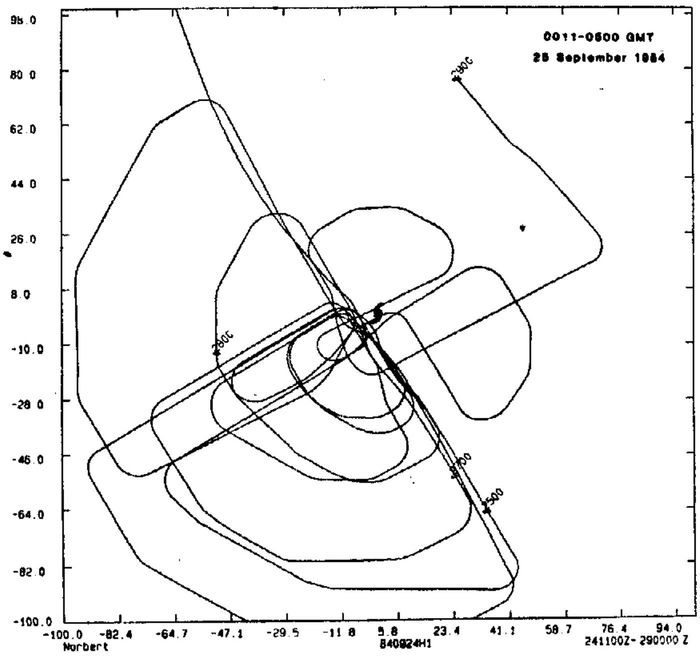

Fig. 2. Flight track of the WP-3D aircraft flying at 6 km altitude. Times are in GMT starting at 0000 GMT 24 September 1984. The origin of the coordinate system is located at the storm center, and the aircraft position are plotted relative to the storm center. Coordinates are east-west distance (X) and north-south distance (Y) in km from the storm center.

Stratiform precipitation was located outside the eye in all sectors but was most prominent south of the storm center. One aircraft flew at an altitude of 3 km and used airborne Doppler radar to map the three-dimensional wind field and reflectivity distribution in the eyewall and surrounding region. The second aircraft flew at 6 km to map the cloud microphysical structure above the $0^{o}C$ level.

2. DATA ANALYSIS

The radar mapping of the wind and reflectivity fields was accomplished by flying the lower-level aircraft in a series of L-shaped patterns with vertices at the storm center (Fig. 1). Three-dimensional fields of wind and reflectivity were constructed from the dual-Doppler analysis and radar time-composite techniques described by Marks and Houze (1984). The L-shaped patterns were ideal for the dual-Doppler analysis, since the flight legs were nearly perpendicular.

The region of dual-Doppler coverage extended 40-50 km away from the storm center., Each L required 16-18 min of flight time, which is the shortest possible time-scale for dual-Doppler analysis with one aircraft. This temporal coverage, while limiting the analysis to echo features with commensurate time scales, is 2 to 3 times better than that in earlier studies.

The second aircraft mapped the microphysical structure over the entire region of dual-Doppler analysis. The flight track (Fig. 2) consisted of a sequence of over-lapping wedge-shaped circuits covering all quadrants of the storm. The most circuits were flown in the southern portion of the storm, where the stratiform precipitation was most extensive and intense. The result was a complete horizontal mapping of all flight-level measurements.

To obtain the mesoscale distribution of cloud microphysical patterns, the track has been divided into 30 s ($\approx$4.5 km) segments. Within each segment, the liquid water content, ice particle concentration, vertical air motion and frequency of occurrence of recognizable ice-particle shapes (e.g., columns, branched crystals, nearly round) are plotted and analyzed. The horizontal distributions of these parameters over the area of the storm constitute the first two-dimensional horizontal mapping of the microphysical structure of a hurricane. The data along the flight track are examined with higher spatial resolution ($\approx$1 km) wherever the track crossed the eyewall.

The temperatures along the flight track at 6 km ranged from about -5 to $-8^{o}C$ outside the eyewall. The complete in situ microphysical sampling at this level is examined in the context of the three-dimensional reflectivity and Doppler-derived wind field analyses described above to reconstruct a comprehensive picture of the air motions and precipitation processes associated with the eyewall and its surrounding stratiform cloud region. The flight-level winds measured aboard the two aircraft are incorporated into the Doppler-derived wind analyses.

In future studies, a water budget of the storm will be inferred from the radar and microphysical analyses presented here. The water budget will be determined by techniques similar to those of Gamache and Houze (1983), who divided the water budget of a tropical squall line into convective and stratiform components. A similar subdivision will be made for the hurricane, with the convective and trailing stratiform regions of the squall line being replaced by the hurricane's eyewall convective ring and surrounding stratiform region, respectively.

3. ACKNOWLEDGMENTS

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4. REFERENCES

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