Extended Abstracts Volume: 16th Conf. on Hurricanes & Tropical Meteorology, May 14-17, 1985, Houston, Texas. Published by American Meteorological Society, Boston, Mass. USA

PRECIPITATION MECHANISMS IN A BAY OF BENGAL DEPRESSION

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1. INTRODUCTION

The mesoscale organization and internal structure of the precipitation areas associated with a monsoon depression over the Bay of Bengal have been described using satellite, airborne radar, and airborne cloud microphysical observations. The data were obtained on 3-8 July 1979, during Summer MONEX.

The synoptic scale setting and vertical motions of this depression have been described by Sanders (1984), and aspects of the cloud formations found near the core of the depression were examined by Warner (1984), and Warner and Grumm (1984). Johnson and Houze (1985), who reviewed the synoptic scale vertical motion studies, and presented preliminary radar and cloud microphysical results for 7 July 1979 they confirmed that precipitation was typically organized in mesoscale areas of combined stratiform and convective structure.

This abstract describes the structure of precipitation features associated with the Bay of Bengal depression on 5 July, emphasizing the mesoscale organization of radar-detected precipitation, and the precipitation growth mechanisms revealed by in situ microphysical observations.

2. DATA

Airborne radar data were obtained from a C-band weather radar on board the NOAA P3 aircraft (Houze et al., 1981). The hydrometeor images were obtained in the 0.1 to 6.0 mm diameter range with Particle Measurement System (PMS) probes (Knollenberg, 1970). Cloud liquid water, vertical velocity and other quantities were also measured along the flight track.

3. RADAR AND CLOUD MICROPHYSICAL STRUCTURE ON 5 JULY

Radar data and the flight track are presented in Fig. 1. The depression was located over the Bay of Bengal, with a closed low-level circulation present at about 20 N, 93 E. Three mesoscale precipitation features, labeled A, B and C, were evident in the radar image.

Feature A was a solid line of convective precipitation with peak reflectivities over 40 dBZ. This line moved southward at a speed exceeding 10 m/s, even though no winds in the region had this vector velocity. This line was trailed by a region of very weak stratiform precipitation (too weak to appear on radar but detected by the microphysical instrumentation on the aircraft). Such radar structure has been observed in winter monsoon cloud clusters (Houze and Churchill, 1984). Features B and C did not display line organizations, but also contained both convective cells and broad regions of stratiform rain. These features were oriented generally northwest to southeast, roughly in alignment with the low-level flow. Note that the precipitation was located primarily from south to southwest of the surface low. This siting relative to storm center has been observed in Indian monsoons over land (Godbole, 1977), and the present study indicates this characteristic is maintained over the sea.

At about 0307 GMT the aircraft entered the northwest corner of feature C. The aircraft was climbing through the 1 deg C level, and detected a few samples of raindrops at that time. For the remainder of the pass through C, the aircraft was between 0 and -2 deg C level. From 0308 - 0346 GMT, the aircraft was in stratiform precipitation. Practically no cloud liquid water was detected, and ice particles appeared to be predominantly aggregates. No recognizable crystal habits were seen except during periods when long thin columns (needles) intermingled with aggregates. Similar aggregates were ubiquitous at the -3 to -4 deg C level in feature B, which was entirely stratiform along the flight track. In B needles were absent except on its north edge. When the aircraft was in regions of stronger stratiform radar echo (0308 - 0322 GMT and 0332 - 0346 in C, 0415 - 0422 in B), the observed aggregates continuously exceeded 3 mm in maximum dimension. In the regions of weaker stratiform echo (0323 - 0331 in C, 0410 - 0415 in B), the aggregates were almost wholly < 3 mm in dimension.

Penetrations of convective regions indicated wholly different precipitation growth processes. From 0347 - 0358 GMT the aircraft was in a region of convective cells in feature C. Intermittent updrafts of up to 5.5 m/s and cloud liquid water peaks of 0.1 to 0.3 g/m^3 (1 s averages) were encountered throughout this period. (The stratiform regions, in contrast, exhibited suppressed vertical motions and practically no liquid water). Upon entering the convection region in C at 0347 GMT, the particle images changed abruptly from prevalent large aggregates to small graupel (nearly round images). High concentrations of needles were formed on both sides of the convection region (0341 - 0345 and 0356 - 0358 GMT).

Feature A, the intense convection line, was traversed at high altitude, (-21 to -23 deg C). Although the radar reflectivity pattern (Fig. 2) did not look very strong due to the high altitude, intense convective updrafts were encountered between 1005 and 1009 GMT; a peak value of 15 m/s occurred at 1007 GMT. These updrafts contained graupel, but very little cloud liquid water (< .1 g/m^3). After leaving the convective region (1010 - 1015 GMT) the aircraft passed through very weak stratiform precipitation (from 1018 - 1030 GMT). This stratiform region was characterized by small irregularly shaped particles, which may have been aggregates. No identifiable crystal habits were evident.

4. CONCLUSIONS

Flights that investigated this Bay of Bengal disturbance on other days observed mesoscale features similar to A, B and C, and collected microphysical data in a range of flight-level temperatures. Stratiform regions were particularily well sampled. The particle images seen at other flight-level temperatures further reveal the precipitation mechanisms operative in the mesoscale stratiform regions. For example, symmetrical six-armed crystals up to 6 mm in diameter were observed recurringly, with maximum frequency near -12 deg C, indicating active growth by vapor deposition at higher levels (probably about the -15 deg C level), and downward flux of particles to flight level. Indeterminably shaped particles, apparently aggregates, were ubiquitous at all levels. Thus, particles drifting downward, growing and aggregating in an environment of weak mesoscale updraft motion, emerges as the prevailing mode of precipitation growth in the stratiform portions of the mesoscale precipitation areas of this Bay of Bengal depression.

ACKNOWLEDGEMENT

This research was sponsored by the National Science Foundation, Grant No. ATM-8413546.

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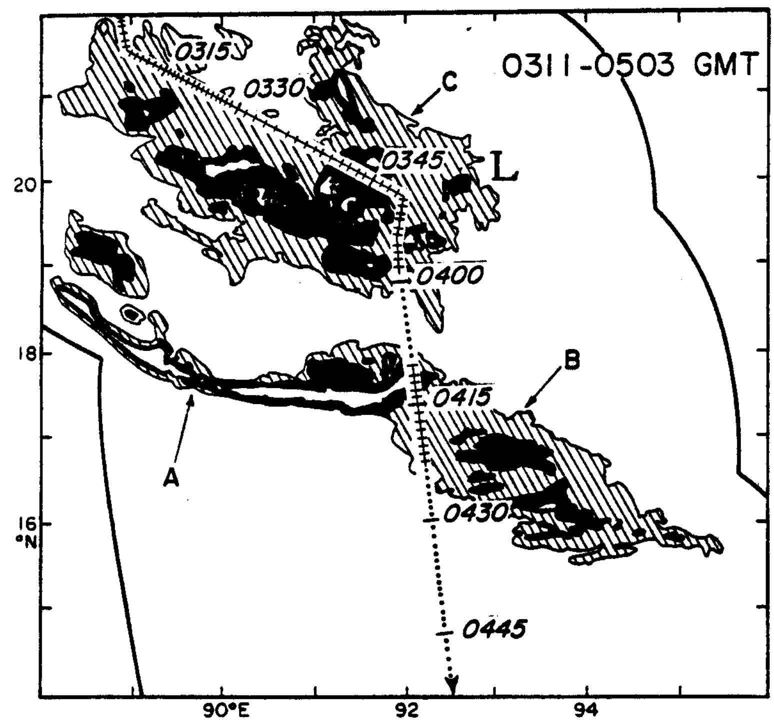

Fig. 1. Composite radar reflectivity and flight track. Contours are at 1, 30 and 35 dBZ. In-cloud flight is indicated by solid line; clear air flight is dotted. Times are in GMT, 5 July 1979.

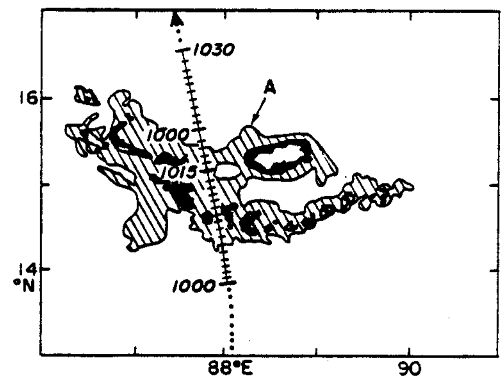

Fig. 2. Composite radar reflectivity and flight track. Contours are at 1, 20 and 25 dBZ. In-cloud flight is indicated by solid line; clear air flight is dotted. Times are in GMT, 5 July 1979.