

# Effect of vertical wind on rain drop size distributions in the boundary layer

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**Abstract** - The height profiles of rain drop size distribution have been studied to understand the role of the vertical drift velocity in the atmospheric boundary layer in changing drop number densities at different heights during convective rain events. The observations with a micro rain radar (MRR) over Kolkata, a tropical location, of rain events pertaining to the period of 2011-15 have been analyzed. A prominent dip in radar reflectivity profiles has been observed near the boundary layer at high rain rates. The results indicate break-up of rain drops into smaller sizes around 2 km height due to strong downdrafts during convective events.

**Index Terms** — Radar reflectivity, Micro rain radar, Convective rain, Drop size distribution, Vertical wind.

## 1. Introduction

The boundary layer dynamics plays an important role in the evolution of rain drop size distribution (DSD) during convective rain events, which constitute an important atmospheric phenomenon at tropical locations [1-2]. A detailed study of the rain parameters is necessary to understand the atmospheric processes responsible for changing pattern of DSD at different heights. Drop size distribution, rain rate and radar reflectivity are important parameters to investigate various types of rain. The profiles of the rain parameters have been investigated to understand the role of vertical wind velocity in changing DSD around the boundary layer.

## 2. Data and Instruments

A micro rain radar (MRR) has been operated at Kolkata (22.57°N, 88.37°E), a tropical location in the Indian region, at 24.1 GHz in FMCW mode which senses DSD at different heights from the Doppler spectrum of the returned radar signal. The height profiles of the radar reflectivity factor ( $Z$ ) are obtained from the DSD measurements. Rain types can be classified into convective or stratiform based on radar reflectivity profiles [3]. Ground based rain information is retrieved from an impact type disdrometer [4] which can sense drop sizes ranging from 0.3 to 5.5 mm. The vertical wind profiles are taken from ECMWF dataset available from the website: <http://apps.ecmwf.int/datasets/data/interim-full-daily/>

## 3. Results and Discussions

Rain rates obtained from disdrometer measurements are classified into the ranges: 1-10 mm/hr, 11-20 mm/hr, 21-40 mm/hr, 41-80 mm/hr and 81-160 mm/hr. A long term study of about 100 rain events during the period 2011 to 2015 has

been made to analyze the reflectivity ( $Z$ ) profiles for various rain intensities. Stratiform rain shows a bright band at a height of about 5 km [5-7]. The height profiles of radar reflectivity at various rain rates are depicted in Fig. 1 which shows a dip in  $Z$  values around the boundary layer. It may be noted that as the rain rate increases the dip in the profile becomes more prominent.

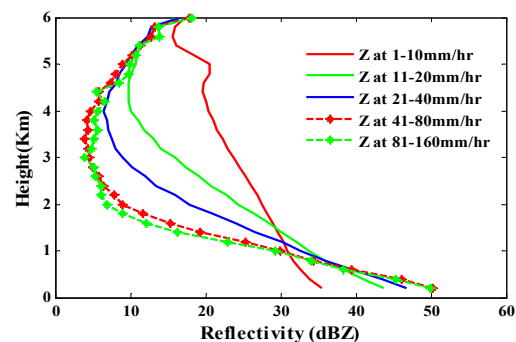


Fig. 1. The reflectivity profile plot for different rain rates.

The height profiles of total number of drops at different rain rates are shown in Fig. 2. Total number of drops is found to be large close to the ground particularly at high rain rates.

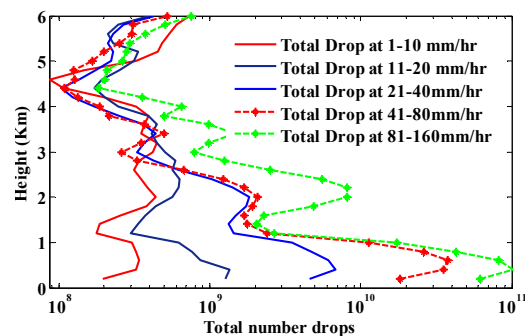


Fig. 2. DSD profile plot at different rain rates

At rain rates greater than 21 mm/hr a secondary peak of drop number emerges at around 2 km height, which is most pronounced at the highest rain rate range. To further investigate this hike in drop number density, the DSD is studied at two drop diameter ( $D$ ) ranges, namely,  $D \leq 2$  mm and  $D > 2$  mm.

From Fig. 3(a) it can be seen that when  $D$  is less than 2 mm, the total number of rain drops are large at lower altitudes around 1 km, while a peak of total number density occurs

around 2 km. However for  $D > 2$  mm, the peak around 2 km disappears for all the rain rate ranges, as shown in Fig. 3(b).

Further, it has been seen that this upsurge of smaller drop number diminishes at 3 km. A ratio of drop number density at 2 km and 3 km ( $N_{2KM}/N_{3KM}$ ) has been calculated to indicate the evolution of rain drop sizes around boundary layer at various rain rate regimes. It is found that the ratio can be as high as 11 at small drop diameters ( $D \leq 2$  mm) and high rain rates ( $> 81$  mm/hr). However, the ratio is less than unity at large drop diameters ( $D > 2$  mm).

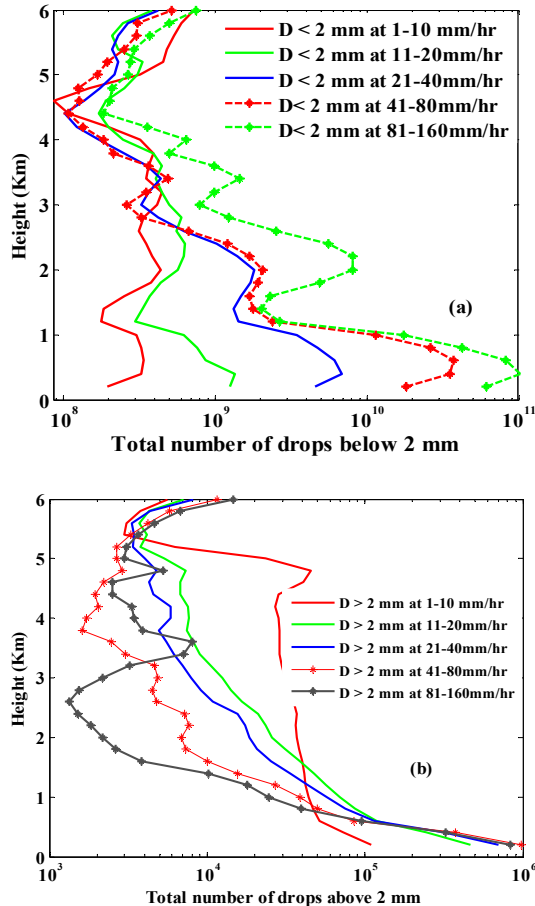


Fig. 3. Drop number densities at two diameter classes: (a)  $D \leq 2$  mm and (b)  $D > 2$  mm.

The above situation leads to the fact that larger drops above 2 km breaks into smaller drops yielding a peak around 2 km. It may be noted that the 2 km altitude corresponds to atmospheric boundary layer where the lapse rate is minimum [8]. To investigate the physical processes responsible for drop break-up, the role of vertical wind has been examined using ECMWF data of vertical wind. Fig. 4 shows the mean vertical wind velocities for those days on which concurrent convective rain events occurred. It may be noted that a dip in negative value (i.e. downdraft) at the 800 hpa pressure level (corresponding to 2 km height) has occurred during intense rain events. It is also to be noted that according to mass conservation, the product of the number density of drops and fall velocity remains constant ( $N(D).V(D)=\text{constant}$ ) [9]. This proposition indicates that an increase in drop velocity results in reduced number density. This will also cause a reduction in radar reflectivity at around 2 km height.

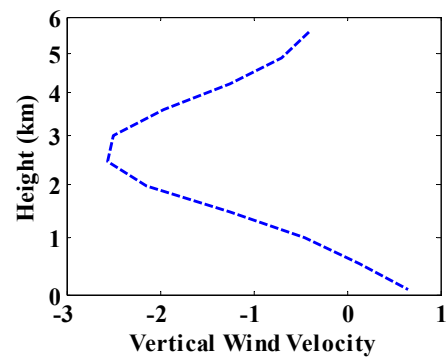


Fig. 4. Vertical wind profile

#### 4. Conclusions

The evolution of drop size distribution at different heights has been studied from micro rain radar observations during convective rain events at a tropical location. The vertical wind velocity in the boundary layer has a crucial role in determining the drop size distribution. A strong downdraft around 2 - 3 km causes breakup of large drops into smaller ones increasing the number density of small drops at that height. This also results in reduction of radar reflectivity as revealed during convective events from MRR measurements.

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