DIAGNOSTIC STUDY OF TROPICAL PRECIPITATING CLOUD SYSTEMS USING WIND PROFILERS AT GADANKI, INDIA

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1. Introduction

The occurrence of deep convection in the tropics plays an important role in the global circulation, since it transports heat, water vapor, and so on, from the PBL to the upper troposphere. The vertical distribution of diabatic heating depends on the vertical structure of the convective system; hence it is important to study the vertical structure of the precipitating clouds occurring in the tropics. An attempt has been made to analyze the measurements made during the two field experiments using multiple radar facility at Gadanki (13.5^{o}N, 79.2^{o}E), tropical India and radiosonde launches to understand the mesoscale convective precipitating cloud systems during South-west (SW: June to September) monsoon and North-east (NE: October to December) monsoon season (October 1997 to 30 September 2000). The first campaign was organized for nearly one-month, extending from 17 July to 14 August 1999. During the second campaign GPS radiosondes were launched from Tirupati (about 40 km to Gadanki) from 28 August to 22 September 2000. The primary scientific objective of both the campaigns was *to understand the organization and evolution of tropical convection at Gadanki, inland region and its role in the atmospheric energy and moisture balance.* Observational periods were organized with three primary goals in mind: 1) examination of the life cycle of convection from the initiation process in the planetary boundary layer (PBL) through mesoscale organization of the deep precipitating cloud systems; 2) classification of vertical structure of precipitating cloud systems; 3) estimation of vertical profiles of raindrop size distribution; 4) melting layer characterization during stratiform precipitation. In this presentation, 2 and 4 are documented.

The melting layer has recently been assessed, as a possible source of uncertainty in microwave rainfall retrievals in stratiform regions (Olson et al. 2001). The characteristics of the melting layer are not only important for understanding the microphysical processes involved in rainfall mechanism but also necessary for rain retrieval algorithms used for the present and future space-borne rain radars such as Tropical Rainfall Measuring Mission (TRMM) precipitating radar (PR) and Global Precipitation Mission (GPM). The current version of the TRMM precipitation radar retrieval algorithm (version 6 of 2A25) uses the Non-coalescence–Non-break up (N-N) model described in Awaka et al. (1985). In order to resolve the uncertainty of the bright band model, it is necessary to go back to experimental data that can provide some physical constraints. For example, using the wind profiler data taken at Gadanki, India during monsoon seasons, it is possible to retrieve the size distribution of rain below the bright band, and, from this, to draw upwardly both the reflectivity and the Doppler velocity profile in the melting particles region.

2. Results and discussions

Observations at Gadanki site with a L-band wind profiler (Reddy., 2003) showed that a profiler is also a useful tool for diagnosing precipitating cloud systems. Figure 1 illustrates the time-height section of a convective system passing over Gadanki-LAWP on 19 September 2000. Figure 1[(a)] shows the equivalent radar reflectivity factor (dBZ). The raindrop size distribution obtained from the surface-disdrometer is shown in Fig.1(b). The environmental conditions during the second experimental period obtained from Tirupati sounding data are utilized for understanding the local environmental conditions around experimental region. The triangle at the surface in Fig.1(a) indicate the launching time of the radiosonde. The Skew T-log P diagram for sonde launched at 1655 LT is shown in Fig.1(c). The results show a relatively dry surface layer with nearly saturated conditions between 850 and 450 mb. This layer is also characterized by westerly flow extending from 850 mb to 500 mb. Above 500 mb, the flow reverses to easterly/northeasterly. The variability in the flow observed during experimental period is typical for the area and was opportune for studying its effect on precipitating cloud system evolution.

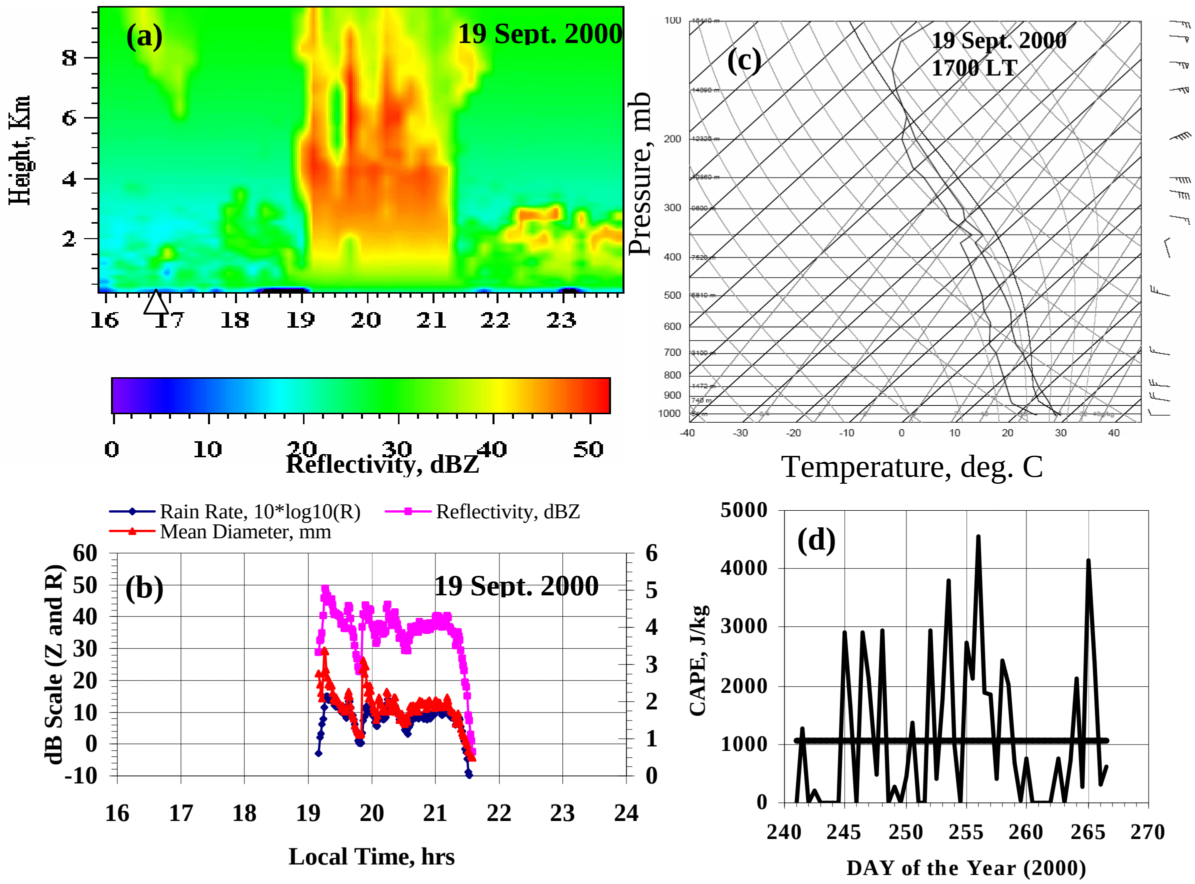

Figure 1. (a) LAWP-measured reflectivity. (b) surface-disdrometer–derived reflectivity, rain rate, and mass-weighted man diameter. (c) Skew T-lop P diagram derived from Tirupati radiosonde observations. (d) Time series of CAPE from 28 Aug. to 22 Sept. 2000.

Convective Available Potential Energy (CAPE) varied considerably during campaign period as shown in Fig. 1(d) and the mean CAPE of 1320 J/kg was observed. There was moderate association between CAPE and environmental flow. Days with a prestorm environment with both low CAPE were evident prior to MCS occurring on 25, 26 November, and 1 December 1995. These days had lower than average total rain volume and associated total rain affected areas. Most days produced a prestorm environment at some time exhibiting a combination of high CAPE (07, 16, 17, 18, and 19 September 2000). Suppression or late development of MCS was sometimes associated with overcast conditions or drier air at low levels. Observations during second experimental period indicated dissipation of initial cumulus clouds and a failure to develop a significant congests stage until late in the afternoon under the latter conditions. Drying of the internal boundary layer by free tropospheric entrainment was always underway competing with the enhancement occurring at the surface through moisture fluxes. This process is described later. Strong convergence associated with sea breeze “collisions” eventually overcame unfavorable conditions resulting in thunderstorm development on such days.

We have tried to examine the accuracy of the so-called non-coalescence – non-breakup (N-N) melting layer model by fitting the model predictions to the L-band wind profiler data taken in Gadanki. Examples for stratified events are shown in Figures 2. Upper plot [Fig.2 (a)] shows the reflectivity data and the middle plot [Fig.2 (b)] shows the Doppler velocity. In the stratiform region, the ‘bright-band’ in the radar reflectivity seen between 4 km- 5 km height represents the melting layer and the height of it depends on the zero degree isotherm. Almost of the data taken during stratification, show the melting -layer height to be in this region. The melting process could also be visible in the Doppler velocity (along the vertical), which was characterized by a sharp increase in the mean-fall speed of the hydrometeors during the snow-to-rain - transition process. The surface-disdrometer derived rainfall integral parameters are shown in Fig.2(c). The input to the N-N melting layer model is either the rain rate or the equivalent radar reflectivity in the rain region just below the melting layer. Assuming a Marshall-Palmer drop size distribution, the measured radar reflectivity just below the melting layer was used to derive $N_R(D_R)$ and, using a simple power law formula for the relationship between the velocity and the drop diameter, the model was evaluated in terms of the radar reflectivity and the Doppler mean velocity. Figure 2(d) shows the comparisons for 18 May 1999 (2-hr averaged radar reflectivity profiles are compared in terms of dBZ/10 in order to use the same x-axis scale as the mean velocity). Such averaging was considered to be necessary in order to reduce the effect of vertical wind component on the fall velocity spectra. The spectra so computed are compared with the measurements in Figure 2(e). The same air-density corrections and the same velocity-diameter relationships were applied as before. The comparisons are shown for three cases (i) the top of the melting layer, (ii) the bright-band peak region and (iii) the rain region just below the melting layer. In all three cases, the N-N model derived spectra agree well with the measurements. This indicates that the velocity dependence on the diameter of melting snowflakes as well as the empirical elements of the model, namely the height variations of the form factor and the water content is sufficiently accurate to represent the melting layer characteristics in Gadanki, at least at L-band. A previous study conducted in the tropics used long-term measurements from an S-band vertically pointing Doppler radar to examine the accuracy of the N-N model (Thurai et al 2003). A similar conclusion was drawn from the S-band data taken in Singapore, although the analyses were conducted only in terms of the height profiles of dBZ, Doppler mean and the spectrum width. The current results give further evidence for the validity of the N-N model for retrieval algorithms for climates affected by monsoon seasons, at least at Rayleigh scattering frequencies.

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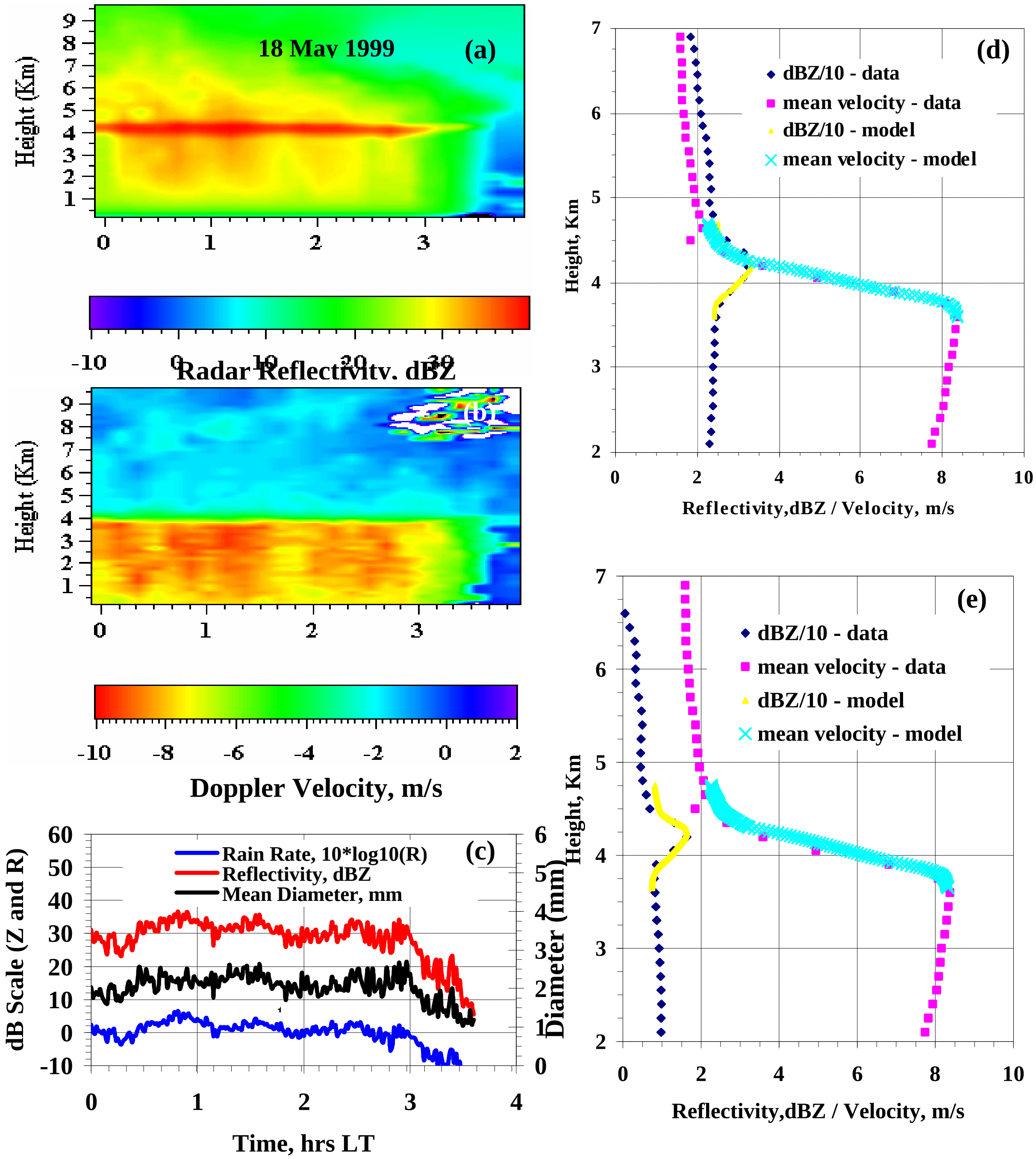

Figure 2. Time-height cross section of (a) Reflectivity (dBZ) and (b) Doppler velocity observed by the vertical beam of the Gadanki LAWP on 17 and 18 May 1999. (c) The 1-min disdrometer-derived rain rate, reflectivity and mean diameter.