DERIVING DROP SIZE DISTRIBUTION FROM VHF AND UHF RADAR SPECTRA

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Introduction

Measurements of Raindrop size distributions (DSDs) are very important in the studies of the growth of precipitation, cloud microphysics and for the improvement of radar estimates of rainfall intensities. DSDs describe the number and size of raindrops in precipitation. The vertical distribution and time evolution of the DSD provide information about the dynamical process of precipitating clouds. Vertically pointing Doppler radar profilers operating at very high frequency (VHF) and ultrahigh frequency (UHF) are potential tools for remotely determining DSDs. This is because, with the help of these radars, we can directly determine the fall-velocity spectrum of the hydrometeors. If the velocity can be related to the size of the falling droplets, then the DSDs can be estimated using Doppler radars. And from VHF radars we can determine the ambient air motions in the precipitating clouds that advect overhead.

The ability of wind profilers (UHF or VHF) to estimate DSDs have been demonstrated by several investigators using various techniques (Wakasugi *et al*. 1986; Gossard 1988; Rajopadhyaya *et al.* 1993). Currier *et al.* (1992), Maguire and Avery (1994), and Rajopadhyaya *et al.* (1998) used the vertical air motion information from a VHF profiler to retrieve precipitation characteristics from UHF Doppler spectra. In this present study, we use this approach to evaluate rain-rate estimation in high and low intensity rain regimes of precipitating clouds. The method assumes a DSD shape. A gamma distribution is used in all the results shown in this paper. A theoretical model is fitted to the radar spectrum and is used to estimate the size distribution of raindrops. The derived rain rate and water content are then compared with the collocated surface disdrometer values recorded at the profiler site.

System Description and Method of Data analysis

The Indian MST Radar, Lower Atmospheric Wind Profiler (LAWP) and disdrometer are located at Gadanki (13.5^{0}N, 79.2^{0}E), in the southern part of India. The Indian MST Radar operates at a frequency of 53 MHz with a peak power of 2.5 MW. Antenna array consisting of 1024 crossed yagi antennas generates radiation pattern with 3^0 half-power beam width. A complete description of the system is given by Rao *et al.* (1995) and Kishore (1995). For the present study we have used a 2-μs pulsed and only 12 beam positions (four in 10^0 off-vertical directions and 8 in vertical direction) corresponding to a range resolution of 300 m and a time resolution of 58 s.

The operating frequency of the LAWP is 1357.5 MHz. The phased antenna array consists of 24 x 24 elements. It transmits a peak power of 1KW. The receiver has a maximum gain of 120dB. This profiler has been configured to operate in Doppler Beam Swinging (DBS) mode. The antenna beam can be positioned, through electrical phase switching, at three fixed orientations, viz., Zenith, 15°down to East and North. The LAWP is operated in two modes, low and high mode, alternatively. In the low mode, radar samples are taken up to 4.8 km with a range resolution of 150 m, while in the high mode the data are collected up to 12.3 km with a range resolution of 150 m. In the present study we have used only vertical beam. A Joss-Waldvogel disdrometer used for measuring DSDs at the ground continuously and automatically. The surface disdrometer records the number and size of raindrops hitting the 50 cm^2 sensor head, enabling the direct calculation of reflectivity, rain rate, water content and D_m.

Data observations and discussions

The observations were made on 22-23 June 2000 and during this period a convective precipitating system passed over observation site. Figure 1 shows the first three moments of the Doppler spectra obtained from LAWP during the above period. During 2200-2300 LT the reflectivity (range corrected SNR) exceeds ~80 dB and net upward Doppler velocities indicates the convective rain regime. During 2300-0600 LT a well defined bright band near 5 km is observed. A significant change in Doppler velocity through the bright-band is seen, which indicates the stratiform rain regime [Williams *et al.* (1995), Narayana Rao *et al.* (2001)].

The contour plot of spectral width in fig. 1(c), shows a values of 1-1.5 m/s in the region of high reflectivity, the spectral width of the ice particles above melting level is found to be less than 1m/s which is less than the spectral width of the echoes from water droplets during stratiform rain which is in the range of 1-1.5 m/s.

Figure 1(d) shows time plot of rain rate recorded with a disdrometer and the rain rate reaches a value of ~70 mm/hr during 2200-2300 LT. However, the rain rate reaches a value of 1mm/hr and remains almost constant for about 5hours during 2300 to 0500 hours LT.

Retrieval Methodology:

In this study it is assumed that the DSD can be represented as a gamma function. The radar reflectivity factor for Rayleigh scatter, Z (mm^6m^{-3}) is proportional to the sixth power of the diameter of hydrometers and is expressed as given by (Doviak & Zrnic 1984). Terminal fall velocity of the raindrops is related to its diameter through empirical relation of Beard (1976, 1977). Finally the observed spectrum can be expressed as given by Wakasugi *et al.* (1986). Which consists of vertical air motion spectrum and fall speed spectrum information.

In general it is observed that the observed height and time of the UHF spectrum do not match with the corresponding height and time of VHF spectrum. Therefore we have taken a mean vertical velocity and spectral width. Important point to be noted is that this retrieval process assumes that vertical air motion spectral width of the two profilers will be the same at both frequencies, but errors associated with this assumption are small Rajopadhyaya (1998). Finally precipitation rate R (mm/hr) and water content (kg/m3) are related to the DSD as given by Rajopadhyaya (1998).

Results:

Clear air information is often very difficult to observe with UHF radars and hence for this reason, the mean velocity and spectral width information obtained from the VHF spectrum is used to identify the position of vertical air motion echo in the UHF spectrum. Thus we can isolate precipitation component of the UHF spectrum fro the clear air component.

Inter comparison of rain rate:

Inter comparison of rain rates and water content retrieved from UHF radar and those obtained by surface disdrometer measurements are made. We have considered the UHF data above 1.5 km onwards because the lowest range that can be probed with the VHF (MST) radar is 1.5 km and we have taken the spectrum at 1.8 km. Figure 2 shows a plot between normalised Doppler spectra and vertical velocity. A least squares fit technique is used to obtain the best possible fit values of the parameters N_0, μ and γ. We have obtained a good fit of the derived spectra to that of the observed UHF spectra. Figure 3(a) shows a time series of rainfall rates measured by disdrometer (dashed), rain retrieved (solid) from profiler at 1.8 km. Figure 3(b) is a time series of water content of disdrometer (dashed) rain retrieved (solid) from profiler at 1.8 km. A good comparison is seen between these two. Here we have sampled the disdrometer values according to that of the UHF time resolution. Figures 4 and 5 show comparison of rain rates at high and low rain rates. At high rain rate some discrepancy is observed and this could be due to time lag between the two instruments or due to the high rain rate Rajopadhyaya *et al.* (1998) and at low rain rate a comparison is fairly good. Figure 6 shows time-height cross section of the retrieved rainfall rate of UHF radar in the high and low rain rate conditions.

Conclusions:

Theoretical model spectra of both clear air and precipitation are derived from the observed spectra. Derived precipitation spectra from UHF radar are in agreement with that of the observed spectra. Rain rate and water content estimates from UHF radar spectra and disdrometer are compared. A fairly good comparison is seen between the two and there is a discrepancy between the two at high rain rates.

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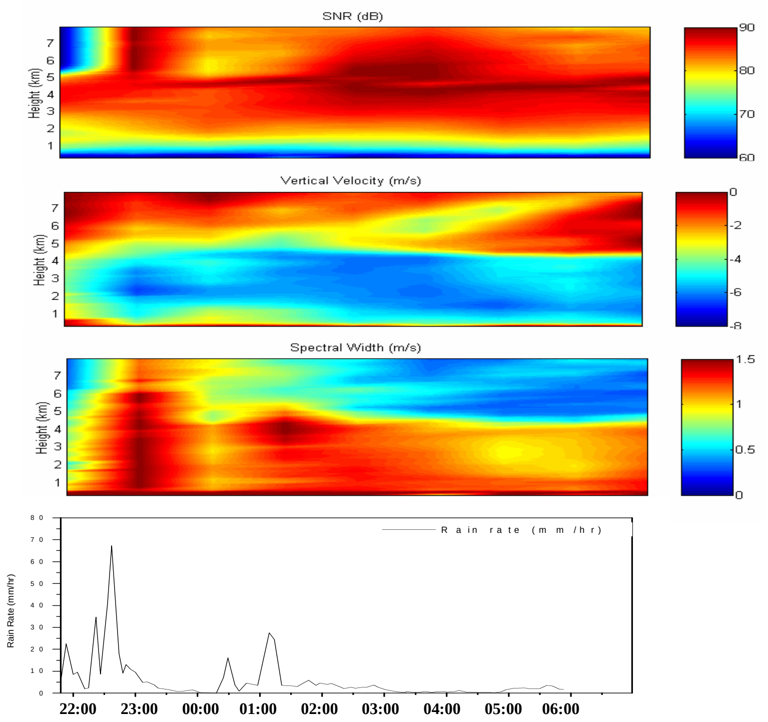

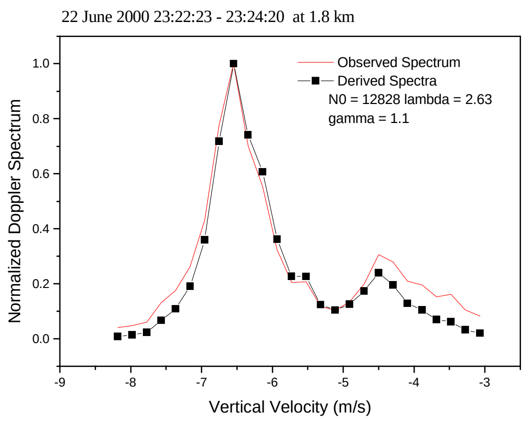

Figure 2: Derived Spectra Versus Observed Spectra

Figure 1: (a) SNR in dB (b) Vertical Velocity (m/s) (c) Spectral width (m/s) Taken from LAWP and (d) Rain rate from Disdrometer

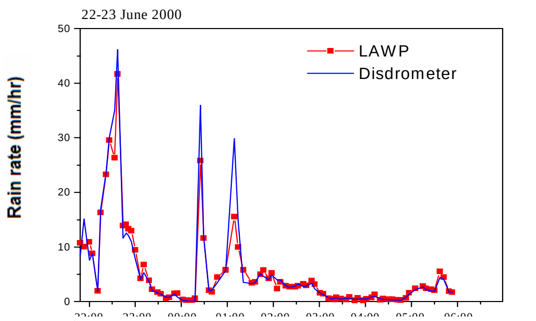

Figure 3a : Comparison plot of time series of retrieved rain rate (mm/hr) from LAWP at 1.8 km and Disdrometer on ground observed on during 22 –23 June 2000

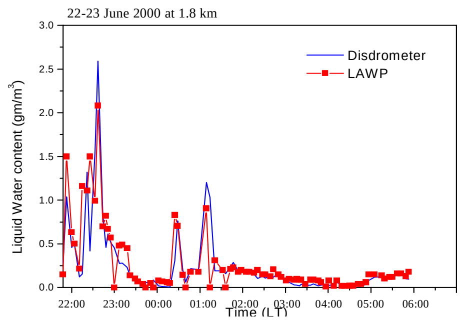

Figure 3a : Comparison plot of time series of retrieved Liquid water content (gm/m^3) from LAWP at 1.8 km and Disdrometer on ground observed on during 22 –23 June 2000

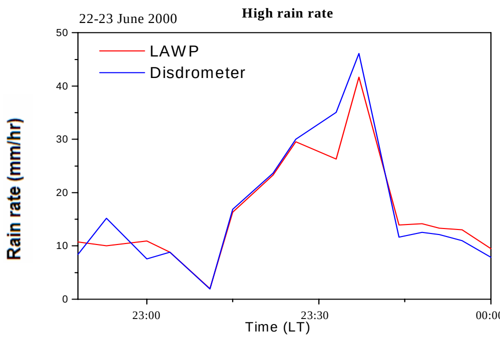

Figure 4: Time series of retrieved rainfall rates from LAWP and in comparison with that of the Disdrometer at the time of high rain rate

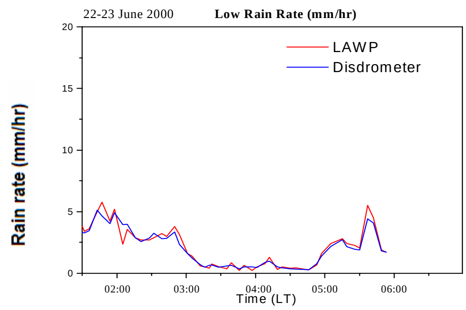

Figure 5: Time series of retrieved rainfall rates from LAWP and in comparison with that of the Disdrometer at the time of low rain rate

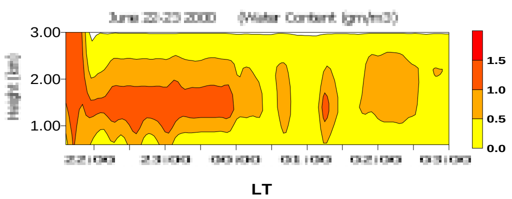

Figure 6: Time series of water content during the period of 22 – 23 june 2000