STUDY OF PRECIPITATING SYSTEMS BY DOPPLER WEATHER RADAR AND TROPICAL RAINFALL MEASURING MISSION PRECIPITATION RADAR

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INTRODUCTION

Doppler Weather Radar (DWR) is used to measure the areal rainfall and three dimensional structures of precipitating systems [1]. The DWR observations are increasingly being used as a data source for hydrological and numerical weather prediction models. DWR works on Doppler Principle with single and dual polarization. In addition to reflectivity, Doppler radar has the ability to estimate the mean radial velocity (V) of targets by measuring Doppler shift in the returned signal.

The Precipitation Radar (PR) in Tropical Rainfall Measuring Mission (TRMM) is aimed in improving the measurement of precipitation from space to achieve more precise estimation of diabetic heating associated with tropical precipitating cloud systems. Precipitation Radar (PR) has the ability to give the vertical profile of latent heat and also precipitation [2]. PR observations are very useful because of its high resolution both in vertical as well as horizontal extent. Vertically it can detect rain profile in 80 different cells at every 0.25 km resolution. Along horizontal direction it can measure rain intensity over a swath of 220 km in 49 Field Of View (FOV) with resolution of ~4.3 km (5 km after 14 August 2001). It cannot sense rainfall rate below 0.5 mm h^{-1}.

In the present paper the tropical precipitating systems are studied over Sriharikota (13.66^0N, 80.23^0E), India, by utilizing DWR [3] and TRMM-PR along with Disdrometer. The operating frequency of DWR and TRMM-PR are 2.8 GHz and 13.8 GHz respectively. One base products of DWR i.e. reflectivity factor Z (dBZ) and two data products from TRMM, namely 2A25 (Z profiles) [4] and 2A12 (latent heat profiles), are utilized for the present study.

METHODOLOGY

Simultaneous observations for DWR and PR are considered whenever there are precipitation echoes. Point to point comparisons of both the radars is obscured by their different scanning method and frequencies. PR is a nadir looking radar and performs a cross track scanning having a beam with of 0.71° and DWR scans in circles in radial directions with horizontal resolution of 0.3 km having beam width of 1°. Bolen et. al. 2000 [5] gives solution to these problems by constructing a three-dimensional volume averaging the PR data in vertical direction with height equal to the beam width of DWR at each horizontal grid point. The footprint of PR is ~5 km and within this region one latitude and longitude value is assigned. In the present paper for the comparison of PR and DWR reflectivity following methodology is adopted. With reference to PR, a threshold of ± 0.04° latitude and longitude is specified. The values of DWR reflectivity within this range are only considered for comparison. After getting different reflectivity values from DWR within this range for one FOV of PR we considered the nearest value with respect to PR reflectivity.

OBSERVATIONS AND RESULTS

Simultaneous observations of precipitation echoes from DWR and TRMM-PR are presented in figure 1(a b, c, d). Figure 1(a,b) shows the observation on 6th November 2003 and 1(c, d) shows

precipitation echoes for both the systems on 7th November 2003. For the 6th November event PR observations are considered at around ~5 Km which is compatible with DWR observations at ~250Km with elevation of 0.5°. For 7th November event PR near surface observations are considered and DWR observations are considered at 0.5° elevation as the precipitation echoes are observed at around ~140 Km. On 6th November it can be observed that reflectivity of PR is underestimated compare to DWR. This may be due to the dissipation or displacement of the precipitating system in a time lag of ~4 minutes. For the 7th Nov. 2003 event the reflectivity values of DWR and PR are also compared. For this particular event PR was nearly overhead of DWR with a time lag of only about one minute. This event covers about 70% of the meteorological echoes within the DWR radius of 300 km. From this figure it can be observed that PR reflectiviy is overestimating the DWR. This may be because of the fact that for Ku band reflectivity can be upto 2 dBZ high in compare to S band due to non-Rayleigh scattering as pointed out by Bolen et. al. 2000 [5] in their study of validating the PR with an S-band polarimetric radar.

Z-R relation is derived from the drop size distribution observed near the validation site at range of about 5 km from the radar. In deriving the Z-R relation the rain rates are divided into two groups *i.e.* one low rain having equal and less than 10 mm hr $^{-1}$ and the other having rain rate greater than 10 mm hr $^{-1}$ with equally distributed rain rates phenomenon. The scatter plot of rainfall intensity and radar reflectivity for both the cases are shown in the figure (2 a & b) respectively. The Z-R relation is fitted into a power law of the form $Z= aR^b$, where 'a' is the coefficient and 'b' is the exponent to be derived. For the low rain category the relation is found to be

$$Z = 211.12 \ R^{1.39}, \qquad R <= 10 \text{ mm hr}^{-1} \qquad (3)$$

and for the higher rain rate category the Z-R relation is

$$Z = 64.20 \ R^{1.78}, \qquad R > 10 \text{ mm hr}^{-1} \qquad (4)$$

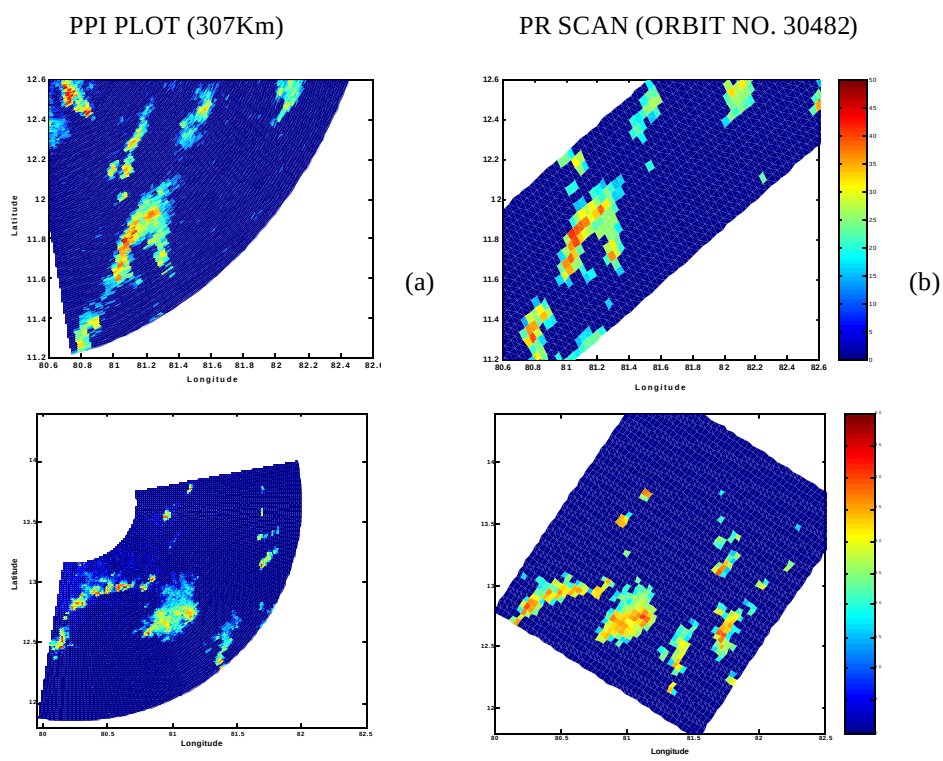
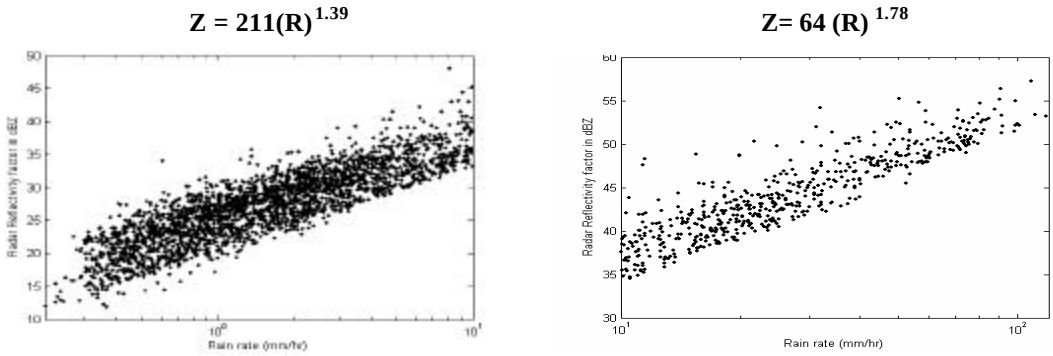


Figure 1: Near simultaneous Observations of DWR and PR (TRMM) (a, b) on 06 Nov and (c, d) on 07 Nov. 2003



(a) (b)

Figure 2: Z-R Relation from Disdrometer Observations at SHAR for (a) low rain (R <= 10 mm hr $^{-1}$) and (b) high rain (R >10 mm hr $^{-1}$)

The scattered plots of the reflectivity factor as observed from both the radars are shown in figure 3(a). Correlation of ~0.9 is observed for the reflectivity factor of PR and DWR. Using these Z-R relations rainfall rate for the corresponding DWR reflectivity is calculated. Scatter plot of rain rate from DWR versus PR is shown in figure 2(b). Correlation of ~0.84 is found between the two radar observations.

Vertical cross section of the DWR and PR reflectivity is also analyzed during the event, where DWR was operated for six elevations viz. 0.5°, 1.5°, 2.5°, 3.5°, 4.5° and 5.5° all in the PPI mode. Figure 4(a & b) shows similar cells of reflectivity echoes for DWR scanning and corresponding PR along scan direction (Ray no. 34). Here PR shows higher dBZ values compared to DWR. High reflectivity of the order of around 40 dBZ is observed up to the height of 6 km in both the cases.

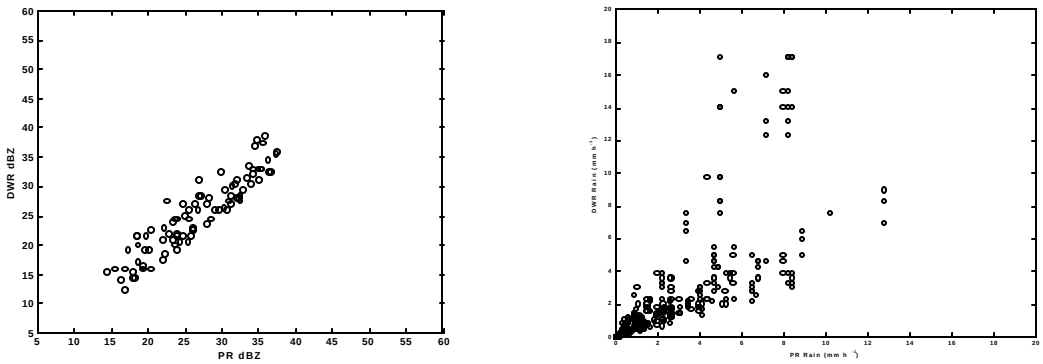
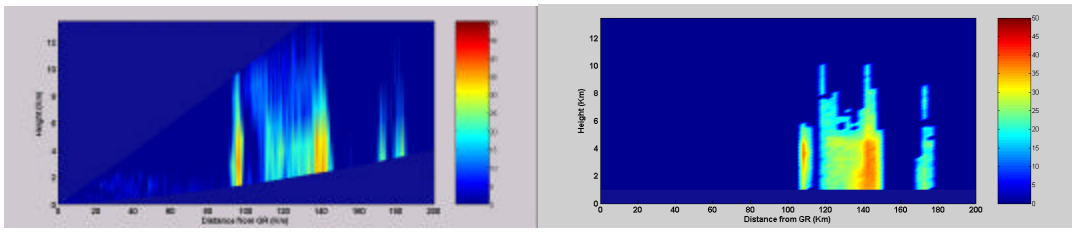
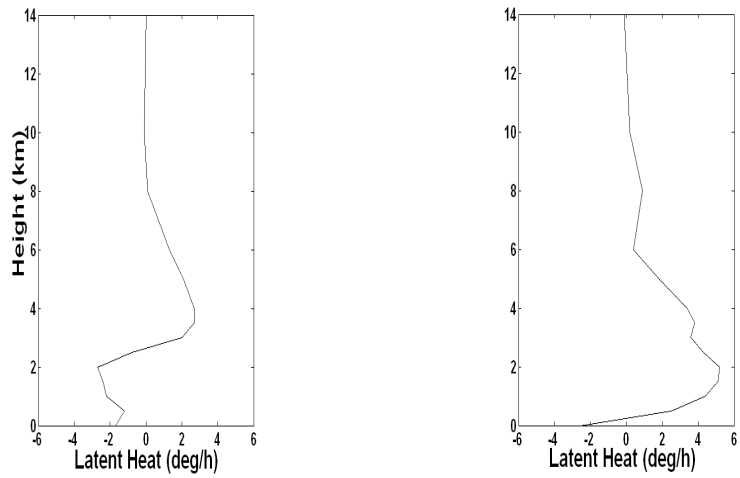


Figure 3: Scatter plot of (a) reflectivity and (b) rain rate for PR versus DWR



(a) (b)

Figure 4: Vertical cross section of (a) DWR (SHAR) and (b) PR for the 7th Nov 2003 event. DWR azimuth 136° corresponds to FOV 34 of PR orbit no. 34082.



(a) (b)

Figure 5: a) Vertical profile of Latent Heat during Stratiform and (b) Convective situations.

Further the vertical profile of the released latent heat is also studied. These profiles obtained from the 2A12 data product for stratiform and convective conditions are shown in figure 5 (a) and (b) respectively. At lower height the distinct pattern of the vertical profile of latent heat is observed. For stratiform it observed to be negative values (cooling) whereas for convective it is positive (heating) [6].

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