RETRIEVAL OF RAIN RATE FROM THE RAIN STATUS OF BMD RADAR

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Abstract

The climate of Bangladesh is characterised by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations. One of the conventional methods of monitoring the meteorological variable rainfall in Bangladesh is radar installed by the Bangladesh Metrological Department (BMD).The BMD S-band radar measures the reflectivity to provide an estimation of precipitation intensity and displays in six rain statuses. This paper presents a method for retrieving the unknown rain rate out of the six rain statuses from the radar plan position indicator (PPI) scan. The technique has been developed to sample the PPI radar scan into 10 km x 10 km grid boxes having 16 pixels with 2.5 km mesh and assemble the data for each status by rain rate retrieval algorithm. A statistical method has also been proposed to retrieve the rain rate at any particular location within radar coverage. Two cases of year 2003 have been analyzed in two distinct periods i.e. pre-monsoon and monsoon for retrieving the rain rates from the rain status. The result from the retrieval method has been tested through a comparison made between the retrieval rain rate measured from BMD radar and the same obtained from the Tropical Rainfall Measuring Mission (TRMM) PR (precipitation radar).

KEY WORD: Precipitation; Radar; Rain Status; Retrieve

1. Introduction

Bangladesh, a low-lying plain land except the hilly southeast, has the climate of being influenced by the monsoon seasonal winds. These winds blow in response to the differences of air temperature over the land area and that over the sea (Ramage, 1971). From the climatic point of view, three distinct seasons can be recognized in Bangladesh - the cool dry season from November to February, the pre-monsoon hot season from March to May and the rainy monsoon season which lasts from June to October (Das, 1995). The rainy season is characterised by southerly or southwesterly winds, very high humidity, heavy rainfall, and long consecutive days of rainfall which are separated by short spells of dry days. Rainfall is the most dominant element of the climate of Bangladesh which governs every instant of life and economy. In one hand it causes widespread flooding, flash flooding etc and in the other hand its lack leads to drought in the country. Hence proper distribution and amount of rainfall throughout the country are important to know for weather prediction, water management, flood forecasting, cloud microphysics, cloud-radiation modelling, climate research, understanding of weather phenomena and agriculture.

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For the last few decades, many methods have been used internationally for the monitoring of rainfall by satellites, either independently or in conjunction with the conventional methods of rain-gauge and radar. In Bangladesh the same is being done using 33 rain-gauges located at different places of the country and weather radar of Bangladesh Meteorological Department (BMD). Due to the intermittent position of rain-gauges it is not potential to expect the precision in amounting of rainfall all over the country. However, the meteorological radar of BMD provides the information of precipitation over Bangladesh. But BMD radar categorises the rain rate only by six rain status, which causes non-availability of the exact value of rainfall rate at a particular position. This has led to work on retrieving precipitation data from the radar image information through some algorithm. It is expected to improve the qualitative and quantitative preciseness to anticipate accurate value of rain rate in order to utilize those data for reference and onward development.

2. Data used and analysis method

2.1 Data used

The plan position Indicator (PPI) scans of BMD S-band radar and the rainfall measured from the space by Tropical Rainfall Measuring Mission (TRMM) 2A25 images have been used in this work. The rain rates obtained from the TRMM 2A25 data products are utilized to calibrate the rain rate retrieve from the BMD radar PPI scans.

2.1.1 TRMM satellite

The TRMM satellite precipitation radar (PR) takes 220 km swath path on the earth surface and passes over Bangladesh once a day to determine convective location, depth, and intensity. As such the data from the TRMM 2A25 image is obtained at a particular moment of the day in 5 km by 5 km grid. Kummerow et al. (1998, 2000) have illustrated the objectives, products, sensors etc of TRMM in elaboration and Huffman (1995, 1997 and 2004) explained the algorithms of TRMM data products. Now-a-days, TRMM satellite is considered as one of the reliable data sources because it carries PR as the first space born radar in the World. The accuracy of TRMM satellite data products is found about 97% (Islam and Uyeda, 2006) in Bangladesh.

2.1.2 BMD radar system

A S-band (10 cm wavelength) weather radar placed on a building roof of about 60 m height at the vicinity of BMD office in Dhaka (90.4^0 N, 23.7^0 E) scans 600 km x 600 km area of the atmosphere on the basis of a regular scanning scheme i.e. one hour at 'ON' and two hours 'PAUSE'. The initial maximum designed radius of BMD radar was 400 km but at present its effective radius is about 250 km. With the present range it can cover almost whole geographical area of Bangladesh except some northwest and southeast portion. The short pulse of high power (500 KW) microwave energy at the frequency of 2800 MHz is produced by the magnetron in the transmitter system. This energy is focused by an antenna system into a narrow beam with beam width of 1.7^0 to travel through the atmosphere at the speed of light (3×10^{8} ms^{-1}). When a target such as a raindrop is encountered, some of the transmitted energy is scattered and of which a minute fraction can achieve the direction back to the antenna system. The sensitive receiver system of the radar processes and amplifies the received power from the precipitation expressed in terms of the reflectivity (dBZ). The effective reflectivity Z is related to the number of drops per unit volume and the sixth power of their diameter and related to rainfall rate R through an empirical relationship called a Z-R relationship i.e, $Z = aR^b$; Where a and b depend on the type of precipitations. The output of the BMD radar receiver is collected as PPI at zero elevation angles at every 2-3 minutes interval and displayed its horizontal cross-section with pixel resolution of 2.5 km. Contours of reflectivity are plotted on the radar charts as a colour coded display. The six colours within these contours indicate six ranges of intensity levels of the rainfall rate as given in Table 1.

Table 1: Radar Intensity Ranges

Colour	Reflectivity (dBZ)	Status	Rain Rate (mm/hr)	Precipitation Description
Blue	0	1	≤ 4	Light
Sky Blue	10	2	≤ 16	Moderate
Green	20	3	≤ 32	Strong
Yellow	30	4	≤ 64	Very Strong
Pink	35	5	≤ 128	Intense
Red	>35	6	> 128	Extreme

2.2 Analysis method

The status levels mentioned in Table 1 have been modified and customized through high level language program and statistical analysis to retrieve the precise data of precipitation. Firstly, C program has been coded to sample for the PPI image of radar display into 60 x 60 matrices of 10 km x 10 km grid box which contains 16 pixels of 2.5 km by 2.5 km mesh. As such a total of 3600 data pixels have been extracted for each status. Thereafter, these 3600 data pixels of each status are used in the following equations to find out the instantaneous and spell rain rates.

Here, the instantaneous rain rate in a grid box per rainy area, R_i is given by

$$R_i = \frac{1}{A_R}\sum_{r=1}^{r=6} S_r A_{R,r} \qquad (1)$$

where r is the rain status, S_r is possible rain rate correspond to each status and $A_{R,r}$ is the rainy area of each rain status and A_R is the sum of $A_{R,r}$ in a 10 km grid box.

If N is the total number of PPI scans during the spell duration, the equation (1) becomes

$$R_S = \frac{1}{N}\sum_{i=1}^{i=N} R_i \qquad (2)$$

where R_S is the spell rain rate.

The instantaneous rain rate of a 10 km grid box per unit area instead of rainy area R_t is then given by

$$R_t = \frac{1}{A_G}\sum_{r=1}^{r=6} S_r A_{R,r} \qquad (3)$$

where A_G is the grid area, which is 100 km^2 in this analysis.
The time based relation of the above mentioned equation (3) provides the hourly rain rate R_H by

$$R_H = \frac{1}{N}\sum_{t=1}^{t=N} R_t \qquad (4)$$

where N is the total number of scans in an hour. Using the equation (4) daily and monthly rainfalls are also calculated.

In this analysis, taking the average rainfall range of each status we use S_r as 2.5, 10.5, 24.5, 48.5, 96.5, and 129 mm/h for r = 1, 2, 3, 4, 5 and 6 respectively.

The above mention retrieved data have been displayed using grads software and compared to the images of TRMM.

3. Results and discussion

3.1 Pre-monsoon case on 13 April 2003

Figure1a shows TRMM 2A25 scan at 22:59 LST on 13 April 2003. It is observed that a convection system ~210 km length is developed in the north side of Bangladesh. The system is a multicell echo which composed of about 5 cells. The vertical structure of the system across 'AB line' (90.45E, 25.5N and 91.30E, 24.5N) is shown in Fig. 1b. It is remarkably a tall convection with a value of ~17 km vertical extension. The strong rain rates are existed from about 1 km to 12 km. Usually such type of convection produces heavy rainfall in pre-monsoon period.

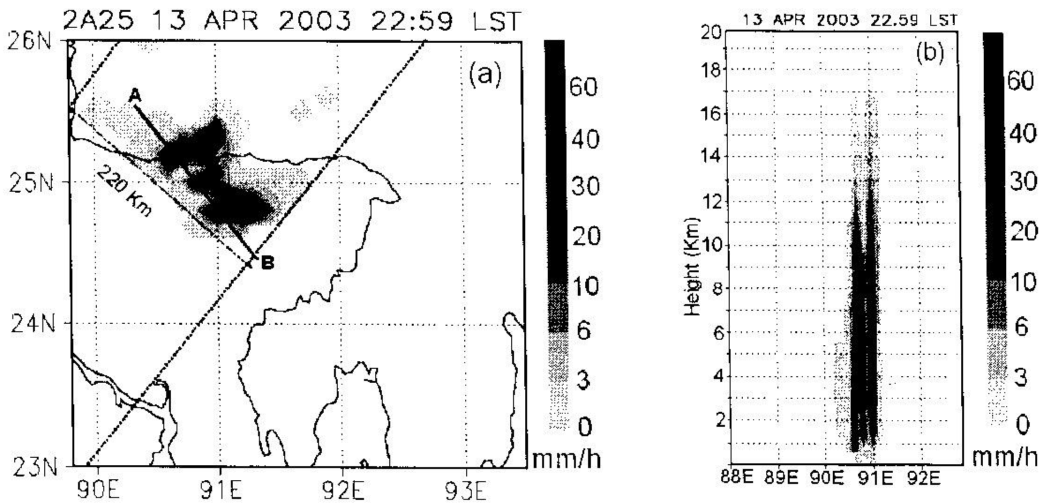

Fig 1. (a) Horizontal scan and (b) vertical structure of precipitation by TRMM 2A25 at 22:59 LST on 13 April 2003. The parallel line shows the TRMM pass.

The convection system, which has been detected by TRMM 2A25 at 22:59 LST on 13 April 2003, is also scanned by BMD radar almost at the same time (23.02 LST). Figure 2a shows the horizontal scan of BMD radar with six rain statuses. Mentionable that BMD radar cannot provide the vertical structure of precipitation due to absence of RHI (Range-Height Indicator) option in its present system. The scattered echoes are observed in the northern side of Bangladesh (Fig. 2a). As mentioned above (Fig. 1a), it is a multicell echo which is not well defined by rain status. From the six rain statuses it is really difficult to articulate the exact rain rate at a particular location. The data from the scanned image (Fig. 2a) has been retrieved using equation 1 to calculate instantaneous rain rates per rainy area and portrayed in Fig. 2b. Hence, it is clear that the retrieved rain rates represent the similar structure of the convective system detected by TRMM 2A25. This result also indicates that the instantaneous rain rates are too closer to the TRMM values. It is noted that the convection events which are visible in the eastern side of the radar image are not within the reach of TRMM pass.

The rainy spell detected by BMD radar for 25 minutes (23:02-23:27) is shown in Fig. 3a. After the retrieval from the same rainy spell using equation 2, the rain rate (mm/h) becomes more specific as shown in Fig. 3b.

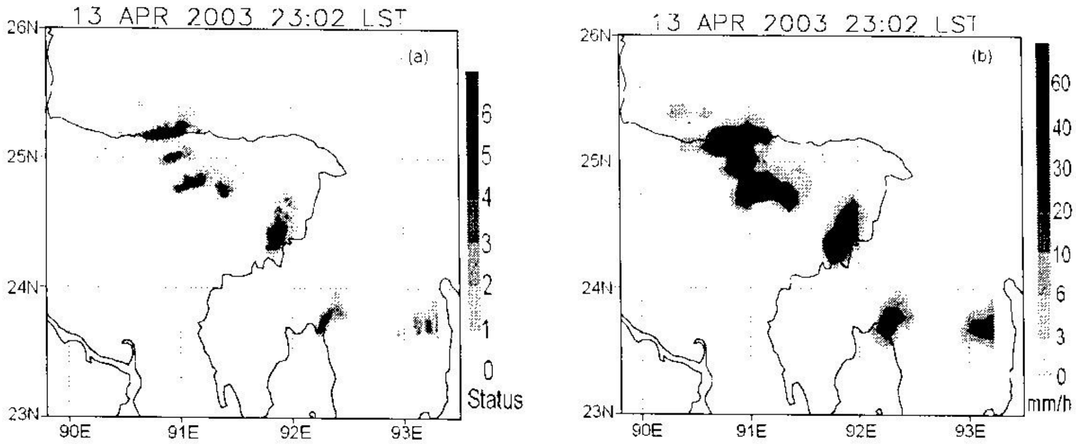

Fig 2. (a) Instantaneous precipitation at 23:02 LST on 13 April 2003 detected by the BMD radar and (b) retrieved rain rate by using equation 1.

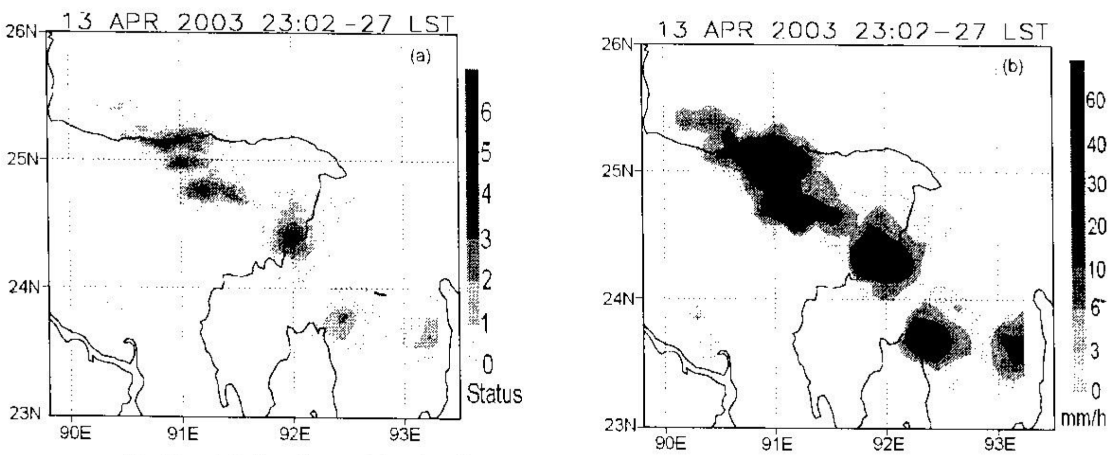

Fig 3. (a) Spell precipitation from 23:02 to 23:27 LST on 13 April 2003 detected by BMD radar and (b) retrieved rain rate by using equation 2

3.1 Monsoon case on 15 July 2003

Figures 4a and 4b show the horizontal scanned image of the convection system of 23:45 LST on 15 July 2003 obtained by TRMM 2A25 and the vertical structure of the same across 90.85E, 24.6N and 91.9E, 24.37N (AB line, Fig. 4a) respectively. The convection system in this case is developed in the east-north-eastern side of the country. The vertical extension (Fig. 4b) in this case is about 13 km. As a result, the intensity of precipitation in the monsoon case is considered lower than that of pre-monsoon. This finding does commensurate with the usual situation of the rainfall characteristics in Bangladesh (Islam and Uyeda, 2006; Kodama et al., 2005).

The TRMM 2A25 detected monsoon case at 23:45 LST on 15 July 2003 is also scanned by the BMD radar at 23:40 on the same date (Fig. 5a). Figure 5b shows the retrieved instantaneous rain rates per rainy area from the six rain statuses. The radar detected echo in the eastern side (over India) is not covered by TRMM pass. For that reason this part of the echo is not appeared in Fig. 4a. Again it is clear that the retrieved rain rates show better patterns of the convective systems compared to rain status.

Figures 6a shows the rainy spell of 28 minutes (23:12-23:40) detected by BMD radar for monsoon case. This spell rain rate (mm/h) is retrieved using equation 2 and represent in Fig. 6b. The retrieved rain rates give a very closer look of the patterns observed by TRMM.

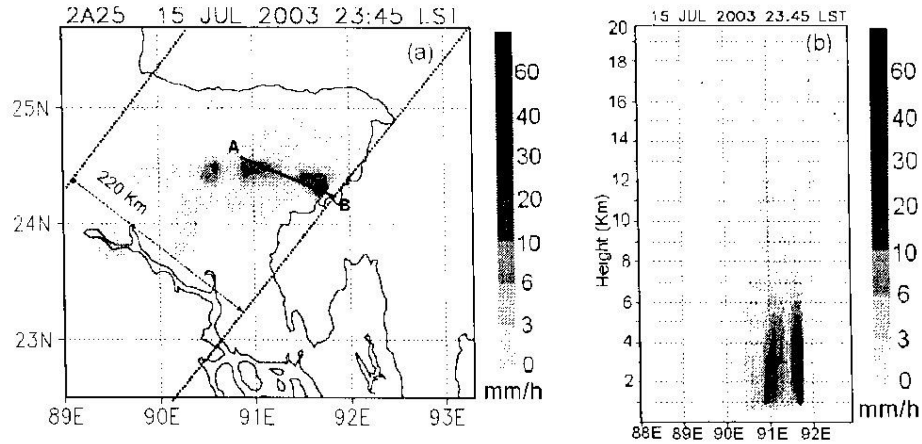

Fig 4. (a) Horizontal scan and (b) vertical structure of precipitation by TRMM 2A25 at 23:45 LST on 15 July 2003. The parallel line shows the TRMM pass.

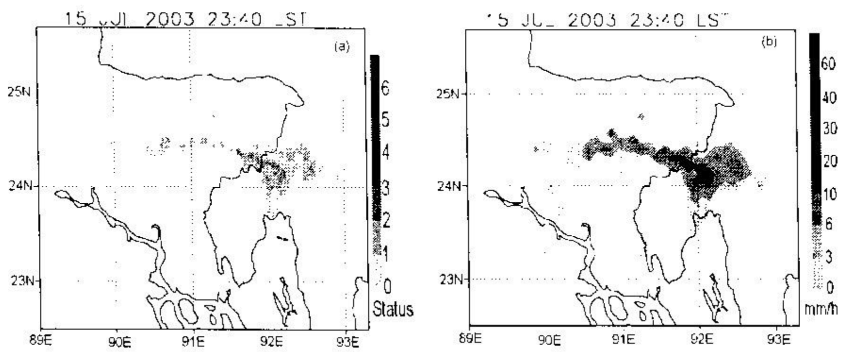

Fig 5. (a) Instantaneous precipitation detected by the BMD radar at 23:40 on 15 July 2003, (b) its retrieved rain rate.

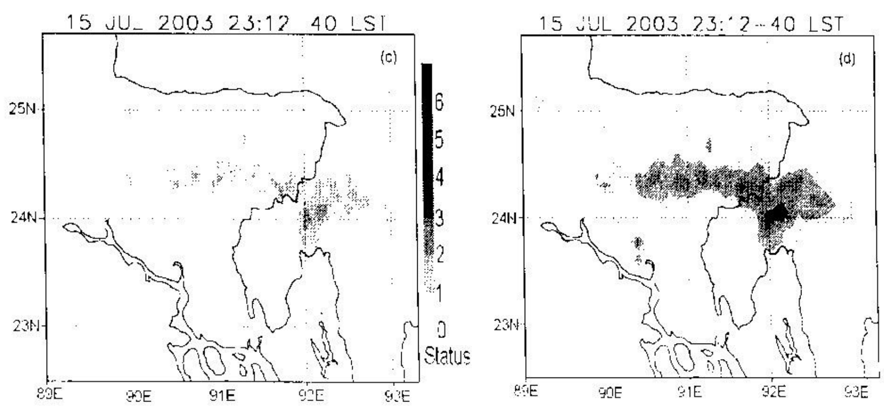

Fig 6. (a) Spell rain rate detected by BMD radar at 23:12-40 on 15 July 2003 and (b) retrieved spell rain rate image.

One can calculate the exact rain rate at a particular location for instantaneous value or rainy spell. Using equations 3 and 4, the rainfall climatology can be obtained from BMD radar PPI scan.

4. Conclusions

The main objective of this work is to retrieve the rain rate from six rain statuses of BMD radar data using proposed algorithms. The algorithms for rain rates retrieval are properly enabled to resolve the intensities and quantities of precipitation. As such, using the said algorithm the accuracy of rain fall data can be achieved. Here, two statistical equations out of four have been used. The rest two equations can be used in the similar way and find out the rain rates per unit area on instant basis, hourly or monthly. The retrieval rain rates from radar PPI scan are found almost similar to the same obtained by the TRMM 2A25. The precise amount of precipitation through retrieval process can play a vital role in short term weather forecasting and for meteorological research purposes in the long run in Bangladesh.

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