Sri Lankan Journal of Physics, Vol. 12 (2011) 7-14

INSTITUTE OF PHYSICS - SRI LANKA

Short Communication

Regional and seasonal variations of precipitation systems in Bangladesh

M. Rafiuddin[1*], Hiroshi Uyeda[2] and M. N. Islam[3]

[1]Department of Physics, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh
[2]Hydrospheric Atmospheric Research Center, Nagoya University, Japan
[3]CECCR, Department of Meteorology, King Abdulaziz University, Jeddah, Saudi Arabia.

Abstract

Regional and seasonal variations of precipitation systems are studied to understand the monsoonal rainfall in Bangladesh using Bangladesh Meteorological Department S-band weather radar Plan Position Indicator scans data and National Centers for Environmental Prediction reanalysis data. Precipitation systems are divided into arc-, line- and scattered-type according to their shape. The arc-type systems are dominant in the all four quadrants with maximum occurrence in the northeastern quadrant during the pre-monsoon period whereas the scattered-type systems are dominant in the southeast, northeast and southwest quadrants during the monsoon period. The arc-type systems are dominant in the northwest quadrant during the monsoon period. In the pre-monsoon period, the arc-type systems may be developed through the interaction of different air masses and the orographic effects in the presence of strong vertical wind shear between the 925 and 500 hPa levels and dry mid level. In the monsoon period, the scattered-type systems may be developed due to plenty of moisture supplied by low-level monsoon winds from the Bay of Bengal and the orographic effects in the presence of little or no remarkable vertical wind shear between the 925 and 500 hPa levels.

Keywords: Precipitation systems; Bangladesh; Pre-monsoon; Monsoon; Radar.

[*] Corresponding author: Email: rafiuddin@phy.buet.ac.bd; rafii015@yahoo.com

1. INTRODUCTION

The South Asian monsoon system, in terms of rainfall, is of great importance to climate researchers for understanding its variability at different space and time scales. The area around Bangladesh (88.05-92.74°E, 20.67-26.63°N) is known as one of the heaviest rainfall areas in the world[1]. The land of Bangladesh is very flat and wet: elevation is about 1-10 m above sea level except small portions in the southeast (elevation ~ 200m) and northeast (elevation ~ 100 m)[2]. A hundred of small rivers including three great rivers flow over the country. Bangladesh has a tropical monsoon climate, with a dry winter and a hot and rainy summer. The winter is cool dry season whereas the rainy season is characterized by southerly or southwesterly winds, very high humidity, heavy rainfall, and long consecutive days of rainfall. Rainy season is divided into three periods: (i) pre-monsoon (March-May), (ii) monsoon (June-September), and (iii) post-monsoon (October-November) periods[3,4]. Islam and Uyeda[5] mentioned that about 20%, 62.5%, 15.5%, and 2% of the annual rainfall (~2700 mm) in Bangladesh occur during the pre-monsoon, monsoon, post-monsoon and winter periods, respectively. Their study indicated that rainfall amounts are different in different seasons. Rafiuddin *et al*.[6] revealed that the arc-type (scattered-type) system is dominant in Bangladesh during the pre-monsoon (monsoon) period. Rainfall is the most dominant element of the climate of Bangladesh, which has strong impact on life and economy. Excessive of rainfall causes widespread flooding, flash flooding etc and on the other hand its lack leads to drought in the country. Hence proper distribution and quantification of rainfall throughout the country are important for weather prediction, water management, flood forecasting, understanding of weather phenomena and agriculture. However still to date it is not clear the regional and seasonal variations of precipitation systems in Bangladesh. The aim of this study is to reveal regional and seasonal variations of precipitation systems developed in Bangladesh.

2. DATA AND METHODS

An S-band weather radar (wave length ~10 cm, beam width 1.7°, elevation angle 0°) is placed on a building roof of ~60 m height in the vicinity of Bangladesh Meteorological Department (BMD) office in Dhaka (23°42′0″N and 90°22′30″E) that scans 600 km × 600 km area (Figure 1) on a regular scanning scheme i.e. one hour at 'ON' and two hours 'PAUSE'. BMD does not operate the radar from 00 to 05 LST (LST = UTC + 6 hours). BMD radar provides only the Plan Position Indicator (PPI) scan with six statuses: 1 (1 mm/h ≤ rain rate < 4 mm/h), 2 (4 mm/h ≤ rain rate < 16 mm/h), 3 (16 mm/h ≤ rain rate < 32 mm/h), 4 (32 mm/h ≤ rain rate < 64mm/h), 5 (64 mm/h ≤ rain rate <128mm/h) and 6 (128mm/h ≤ rain rate). There are about 20 PPI scans (2-3 minutes interval) available during in each operation hour. Because of radar data availability issues, analysis is made only for the pre-monsoon and monsoon periods. The BMD did not properly archive radar data for March and post-monsoon months during the analysis period. Thus April and May data are analyzed to represent the pre-monsoon period.

The study area is shown by a rectangle in the regional map of Figure 1. The rectangular study area is divided into four quadrants- northwest (NW), northeast (NE), southwest (SW) and southeast (SE). Some parts of the northeast and southeast quadrants have high elevation. In the data sampling, precipitation systems having a lifetime equal to or longer than 3 hours and a dimension equal to or longer than 100 km (at least in one direction) are analyzed. From the available scans, precipitation systems are classified on the basis of their shape when they appear to be in the mature stage. The highest intensity of the rain rate and longest length of the system from the available PPI scans are considered to indicate the mature stage.

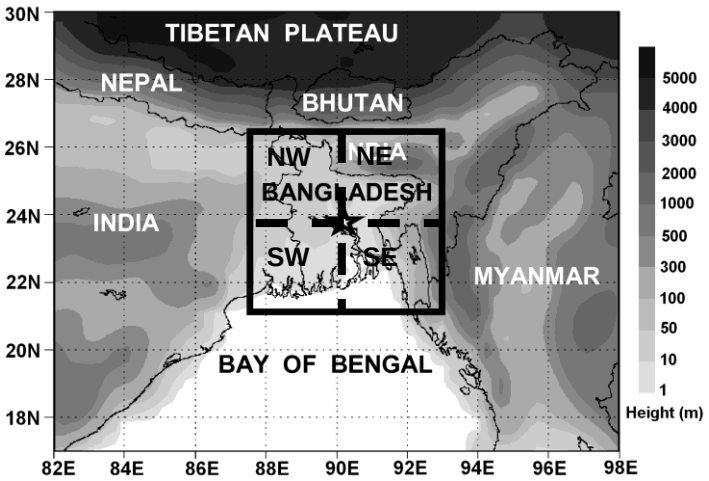

Figure 1: Regional map showing the BMD radar coverage of 600 km × 600 km (solid rectangle). The star indicates the location of the BMD radar. The radar coverage is divided into northwest (NW), northeast (NE), southwest (SW) and southeast (SE) quadrants. The topography is shown by the gray shading.

Classification of precipitation systems is done according to Rafiuddin *et al.*[6], who revealed details characteristics of the different types of precipitation systems in Bangladesh using the same data set. In this paper we would like to focus on the regional and seasonal variations of precipitation systems in Bangladesh. An important difference from Rafiuddin *et al*.[6] is that in this study we used a normalization technique to find the relative frequency of occurrence of system. This simplified normalization technique is based on the idea proposed by Araogao *et al.*[7] for irregular PPI scans (time of observations). The relative number of system and the relative frequency of each type were separately obtained for each month, based on the formula.

$$\text{Relative number of system}\left(RNS\right)_x(m) = \frac{\text{Absolute number of system}\left(ANS\right)_x}{\text{Total PPI in the month}(m)}$$

$$\text{Relative frequency of system}\left(RFS\right)_x(m) = \frac{\text{Relative number of system}\left(RNS\right)_x(m)}{\text{Total relative number of system}\left(TRNS\right)_x(p)} \times 100\%$$

$$\text{where, } x = \text{type of system, } m = \text{month, and } p = \text{total period}$$

Precipitation systems are classified into three types: arc-, line-, or scattered-type: i) Arc-type systems (having an arc-shaped strong leading edge and a stratiform (weak echo) region behind), ii) Line-type systems (having linearly shaped echoes and sometimes embedded within weak echoes), iii) Scattered-type systems (composed of groups of poorly organized small individual echoes, with less than 50 km as the maximum distance between echoes)[6]. Actually, a scattered-type system could be composed of many small isolated echoes and a few wide (large) echoes. Some scattered-type systems extend over relatively small areas, and other scattered-type systems have wide areal coverage called SWAC. The above categorizations are made subjectively after careful observation of the shape of a system in its mature stage. The system location is calculated from the approximate centre of the system in the mature stage.

The environmental wind field for individual case studies is obtained using National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) 6-hourly reanalysis data on a 2.5 degree × 2.5 degree global grid. The seasonal 6-year average (mean) environmental wind field is obtained from the same dataset.

3. RESULTS AND DISCUSSION

The development of arc-, line- and scattered-type systems is found 54% (14%), 19% (13%) and 27% (73%) in the pre-monsoon (monsoon) period, respectively. Figure 2 shows the regional distribution of the arc-, line- and scattered- types systems in the pre-monsoon and monsoon periods.

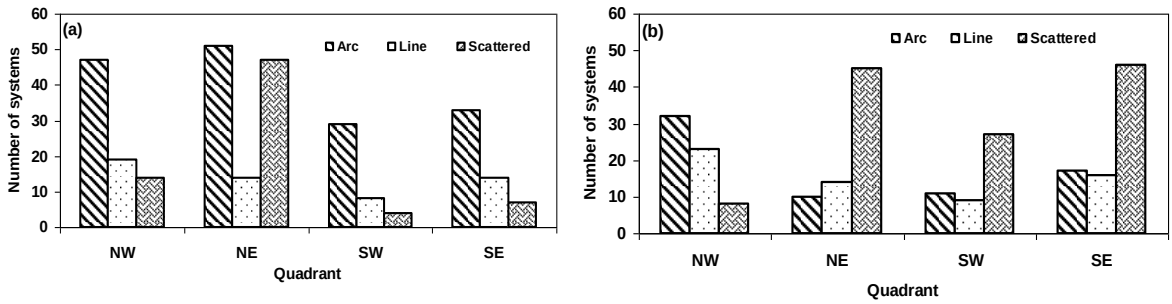

Figure 2: Distribution of the arc- (diagonal hatched), line- (light dot shading) and scattered- (cross diagonally hatched) types systems by quadrant: (a) pre-monsoon, (b) monsoon.

In the regional analysis, 244 SWACs are not included because of their wide areal extend. During the pre-monsoon period, the arc-type systems are predominant in the all quadrants with maximum in the northeast quadrant. However, there is little difference in the number of arc-type systems in the northeast and northwest quadrants. In the northeast quadrant, the contribution of scattered-type system is also significant during the pre-monsoon period. The highest occurrence number of line- and scattered-type systems is found in the northwest and northeast quadrants during the pre-monsoon

period, respectively. During the monsoon period, the scattered-type systems are dominant in the northeast, southeast and southwest quadrants whereas the arc-type systems are dominant in the northwest quadrant. The highest occurrence of scattered-type system is found in the southeast quadrant. However, there is little difference in occurrence number of scattered-type systems in the northeast and southeast quadrants. The highest occurrence of arc- and line-type systems is found in the northwest quadrant during the monsoon period. These two type systems contribute in the monsoonal rainfall of the northwest quadrant.

Figure 3 represents that the pre-monsoon systems are dominant in the northwest and northeast quadrants whereas the monsoon systems are dominant in the southwest and southeast quadrants. The maximum occurrence of pre-monsoon systems is found in the northeast quadrant whereas the maximum occurrence of the monsoon systems is found in the southeast quadrant.

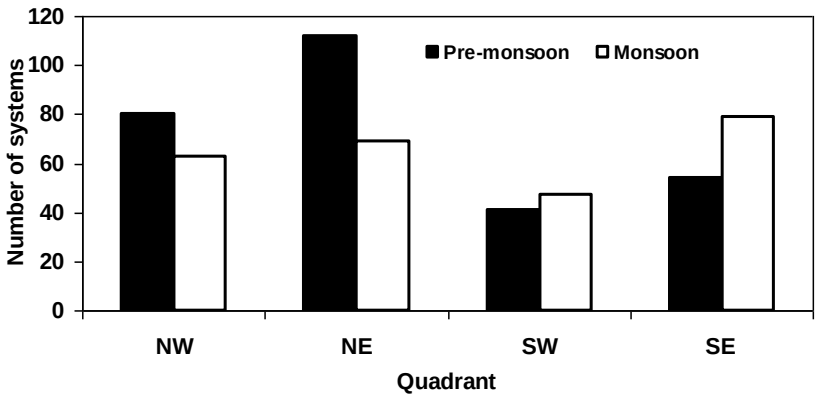

Figure 3: The seasonal distribution of systems by quadrants during the study period.

The pre-monsoon is the transition period from the winter monsoon to summer monsoon circulations. The insolation is very intense which helps to develop a heat low over the subcontinent. Bangladesh and its adjoining regions are under the influence of a low pressure system (or an extended trough of low pressure). The subtropical seasonal high shifts to the Bay of Bengal during this period. In general, the low level winds are southerly or southwesterly which lead to a well marked shallow inflow of moisture from the Bay of Bengal into the Bangladesh, while in the mid upper troposphere a moderate to strong westerly flow, often associated with westerly jet, continues over the northeastern part of Indian subcontinent[8,9].

The orography of the eastern and northern sides of Bangladesh has strong impact on the organization of precipitation systems. The orography of northeastern side of Bangladesh enhanced the development of pre-monsoon systems in the northeast quadrant. The orography of southeastern side of Bangladesh enhanced the development of monsoon systems in the southeast quadrant.

Figure 4 shows the seasonal variability of occurrence of arc-, line- and scattered-type systems from 2000 to 2005. From this figure it is clear that there have strong intraseasonal variation of precipitation systems in different years.

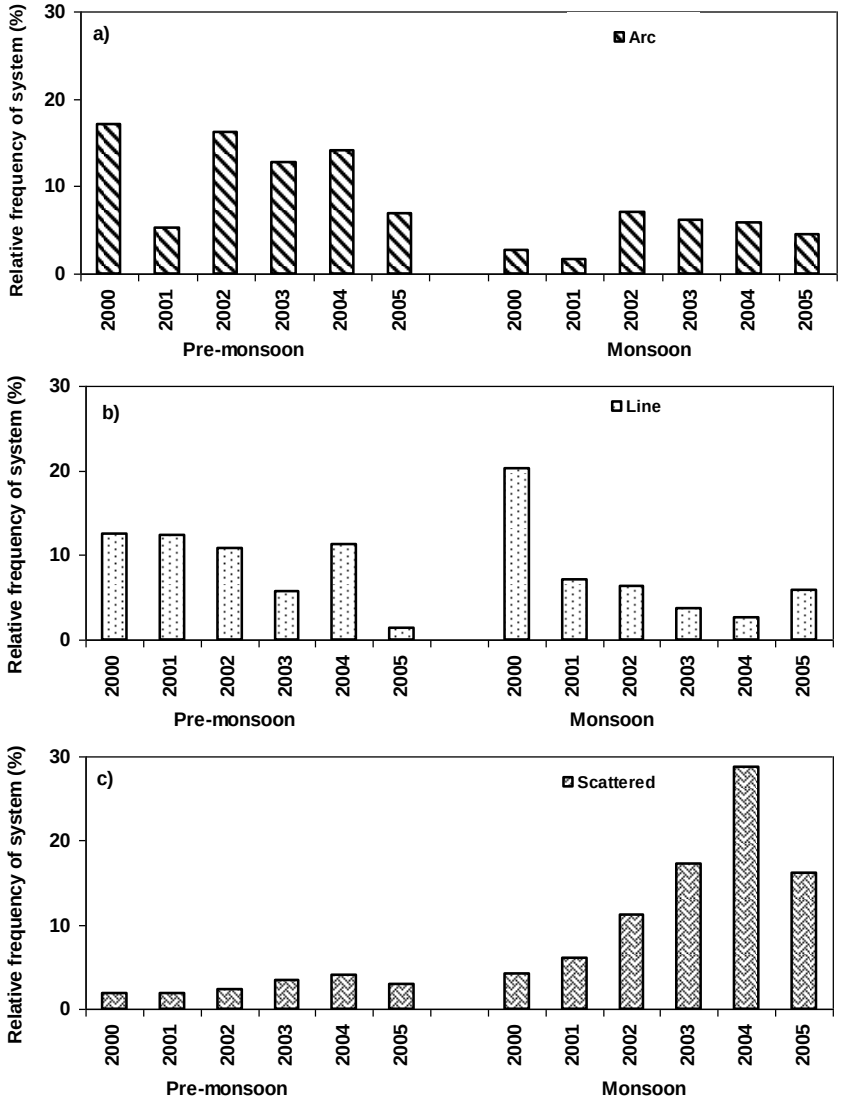

Figure 4: The intraseasonal variation of the relative frequency of systems types in different years: (a) arc-type, (b) line-type, and (c) scattered-type systems. The total percentage of each type of system is assumed to be 100%.

Figure 5 shows the average seasonal variation of relative humidity (%) and wind field (arrow) at 925 and 500 hPa levels during 2000-2005. During the pre-monsoon period, the average low level (925 hPa) wind is southwesterly or southerly and relative humidity is about 60% and the mid level (500 hPa) wind is strong westerly or northwesterly and the relative humidity is about 15% (Figure 5 (a-b)). The vertical wind shear is strong between the 925 and 500 hPa levels in the pre-monsoon period. The pre-monsoon systems, especially the arc-type systems, may develop through interaction with other air masses and the orographic effects in the presence of strong vertical wind shear

and dry mid level. During the monsoon period, the average low level (925 hPa) wind is strong southerly or southwesterly and the relative humidity is about 90% and mid level (500 hPa) wind is southerly or southwesterly and the relative humidity is about 60% (Figure 5 (c-d)). The vertical wind shear is very small in the monsoon period. Monsoon systems, especially scattered-type systems, may develop from the ample moisture supplied by monsoonal wind and the orographic effects in the presence of little or no vertical wind shear between the 925 and 500 hPa levels. In general, the western part of the country is less humid than the eastern part during the pre-monsoon and monsoon periods.

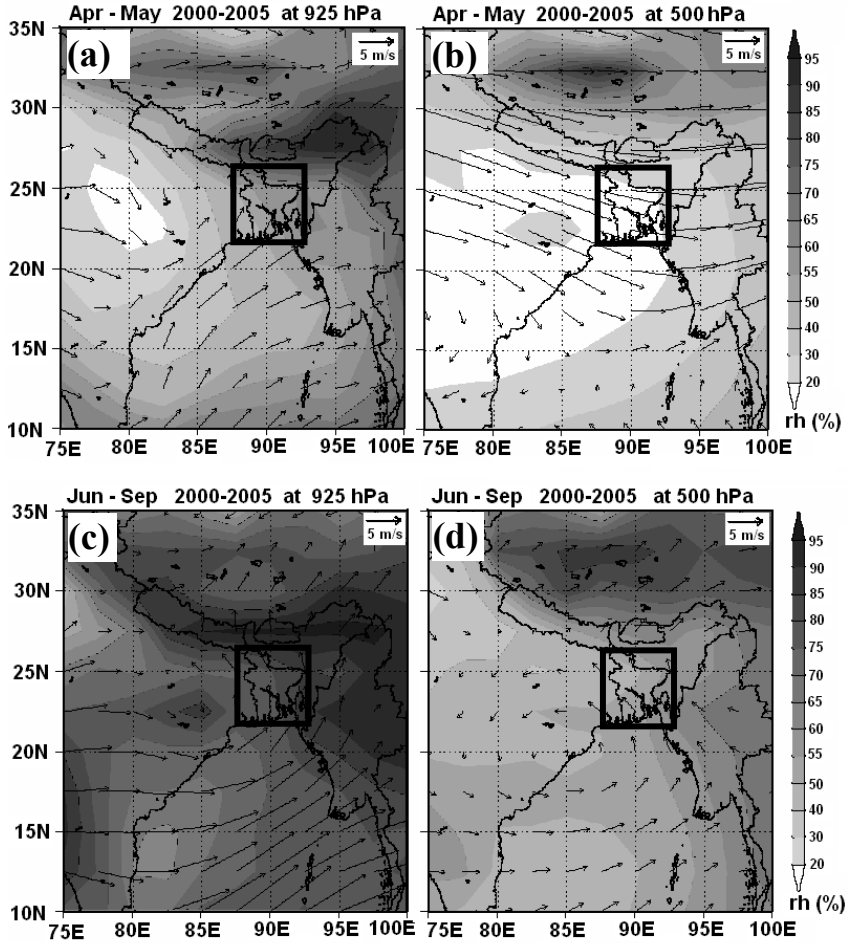

Figure 5: Average seasonal variation of relative humidity (gray shading) and wind field (arrow) for (a-b) pre-monsoon and (c-d) monsoon periods at 925 and 500 hPa levels.

The pre-monsoon precipitation system is usually associated with the occurrence of deep convective thunderstorm. The occurrence of the pre-monsoon system depends on the moisture supply by the low level wind from the Bay of Bengal and interaction with hot and dry air coming from India. Monsoonal precipitation system is usually associated with the occurrence of monsoonal depressions, low pressure systems and cyclonic circulations and their position. The occurrences of these synoptic modes change the seasonal frequency of precipitation systems.

4. CONCLUSIONS

The development of arc-, line- and scattered-type systems in Bangladesh is found 54% (14%), 19% (13%) and 27% (73%) during the pre-monsoon (monsoon) period. Regional analysis showed that the arc-type system dominant in the all quadrants with maximum in the northeast quadrant during pre-monsoon period. The scattered-type system is dominant in the northeast, southeast and southwest quadrants and the arc-type system is dominant in the northwest quadrant during monsoon period. The occurrence of scattered-type system is maximum in the southeast quadrant.

ACKNOWLEDGEMENTS

The authors express their gratitude to all those involved with producing and disseminating the datasets used in this study. This study was partly supported by the Japan Science and Technology Corporation and a Grant-in-Aid for Scientific Research of the Japan Society for the Promotion of Science, and the Ministry of Education, Culture, Sports, Science, and Technology, Japan.

REFERENCES

1. J. Matsumoto, *Synoptic features of heavy monsoon rainfall in 1987 related to the sever floods in Bangladesh*, Bull. Geogr. Univ. Tokyo, 20, 43-56 (1998).
2. M.N. Islam, T. Hayashi, H. Uyeda, T. Terao and K. Kikuchi, *Diurnal variations of cloud activity in Bangladesh and north of Bay of Bengal in 2000*, Remote Sens. Environ., 90, 378-388 (2004).
3. P.K. Das, The Monsoons (3rd edition), New Delhi, India: National Book Trust, (published by the Director, 1995).
4. M.N. Islam and H. Uyeda, *Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh*, Remote Sens. Environ., 108, 264-276 (2007) doi:10.1016/j.rse.2006.11.011.
5. M.N. Islam and H. Uyeda, *Comparison of TRMM 3B42 products with surface rainfall over Bangladesh,* Preprints in the proceedings of International Geoscience and Remote Sensing Symposium (IGARSS) 2005, Seoul, South Korea, July 25-29, 2005 (pp. 4112-4115). 4TH127A_05.
6. M. Rafiuddin, H. Uyeda and M.N. Islam, *Characteristics of monsoon precipitation systems in Bangladesh*, Int. J. Climatol., 30, 1042- 1055 (2010), doi:10.1002/joc.1949.
7. S.M.R Aragao, M.F. Correia and H.A. Araujo, *Characteristics of C-band meteorological radar echoes at Petrolina, northeast Brazil,* Int. J. Climatol., 20, 279-298 (2000).
8. K.J. Weston, *The dry-line of northern India and its role in cumulonimbus convection,* Quart. J. R. Met. Soc., 98, 519-531 (1972).
9. D. Lohar and B. Pal, *The effect of irrigation on pre-monsoon season precipitation over the west Bengal, India*, J. Climate., 8, 2567–2570 (1995).