Characteristics of monsoon precipitation systems in Bangladesh during 2000-2005

M. Rafiuddin[1, 2], Hiroshi Uyeda[1] and M. N. Islam[2]
[1]Hydrospheric Atmospheric Research Center, Nagoya University, Japan
[2]Department of Physics, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh

Abstract

Precipitation systems developed in and around Bangladesh (88.05-92.74°E, 20.67-26.63°N) are classified into Arc, Line and Scattered type according to their shape by using radar data from 2000 to 2005. The systems are further subdivided according to their lengths which are small, medium and large. On the basis of speed the systems are subdivided into stationary, slow and fast moving. Scattered type systems dominate in monsoon months and Arc type in pre-monsoon months. Line type contributes in number almost equally in both seasons. In general monsoon systems are large and stationary or slow moving compared to the pre-monsoon.

1. Introduction

The southwesterly monsoon flow connects the South Asian and East Asian monsoons. The development mechanism of precipitation systems in a moist environment such as the Meiyu/Baiu frontal region in East Asia and Bangladesh in Southeast Asia is interesting to understand monsoon rainfall. The area around Bangladesh is known as one of the heaviest rainfall areas in the world (Matsumoto, 1988). Heavy rainfall over this area acts as an important part of the atmospheric heat source that controls the Asian summer monsoon circulations (Ose, 1998; Li and Yanai, 1996 and Luo and Yanai, 1983). Heavy rainfall often causes flood or flash flood in Bangladesh. Studying the development mechanism and detailed characteristics of precipitation systems for heavy rainfall in a region like Bangladesh is very important for understanding characteristics of monsoon precipitation and model parameterization. The precise idea of distribution and characteristics of precipitation systems are also helpful for disaster prevention and water management of agriculture-dependent country like Bangladesh.

The size, organization and motion characteristics of the precipitation systems are the key factors that determine whether those produce heavy rainfall. A preliminary work using one year radar data is reported by Islam et al. (2005) and they found that the location of the development of precipitation systems is 60%, 21% and 19% in the northern, central and southern part of the country respectively. Islam et al. (2004) has shown that the speed of the precipitation system is faster in pre-monsoon and development side of the echo is almost northern part of the country. The lifetime and movement speed of the precipitation systems developed over Bangladesh is reported about 5.7 hr and 5 m/s respectively (Islam et al., 2005).

So far there are no research work carried out by using long term radar data about the classification and characteristics such as length, duration, propagation speed and direction of the precipitation systems in monsoon and pre-monsoon. Bangladesh Meteorological Department (BMD) radar data is available to study the characteristics of precipitation systems from 2000. In the present article total 6 years data is analyzed and discussed in details.

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 BMD office in Dhaka (23°42′0″N and 90°22′30″E) that scans 600 km × 600 km area (Fig. 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) 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. The 91673 PPI scans of the years 2000-2005 (April to September but no data in April for 2001 and 2005, and August for 2002, and September for 2000, 2001 and 2003) have been used in this analysis.

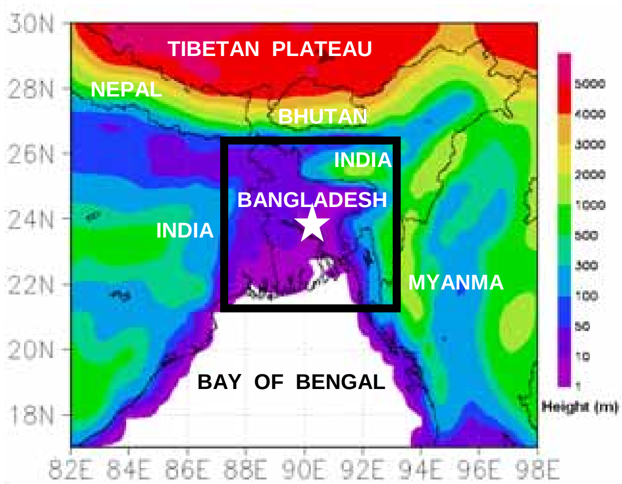

Fig. 1. Regional map showing BMD radar coverage (solid rectangle). The star mark shows the location of the BMD radar.

Precipitation systems having lifetime ≥ 3 hr and dimension ≥ 100 km (at least in one direction) have been considered for analysis. The precipitation systems are divided into three categories on the basis of their shape when it seems to be in mature stage among the available scans which are: i) Arc type (having arc shape leading edge and behind has weak echo (Fig. 2a)), ii) Line type (having strong linear shape echo sometimes within weak echoes (Fig. 2b)) and iii) Scattered type (not well organized small individual echoes distributed in certain area (Fig. 2c)). Some of the Scattered type systems are spreading relatively small area and for this type of systems the studied parameters have been calculated. While remaining Scattered type systems have wide areal coverage as shown in Fig. 2d; we named it SWAC. For SWAC, the studied parameters have not been possible to calculate. The average speed of the system has been calculated from the movement of the convection line. If the convection line is not detectable then center of gravity has been considered for calculating the speed. In such case, echo intensity of the system having less than status 1 (≤ 4 mm/h) is not considered. The different type of systems are subdivided according to their lengths which are small system (SS, 100 km ≤ SS < 200 km), medium system (MS, 200 km ≤ MS < 300 km) and large system (LS, 300 km ≤ LS). On the basis of speed, the different type of systems are further subdivided into stationary (≤ 2 m/s), slow (2 m/s ~ 7 m/s) and fast moving (≥ 7 m/s). The approximate life time of the system is calculated from available scans. The highest intensive rain rate and the largest length of the system from the available PPI scans is considered as mature stage. Propagation direction of the system is calculated at the mature stage. In this work, April and May are considered as pre-monsoon period because data for March is unavailable.

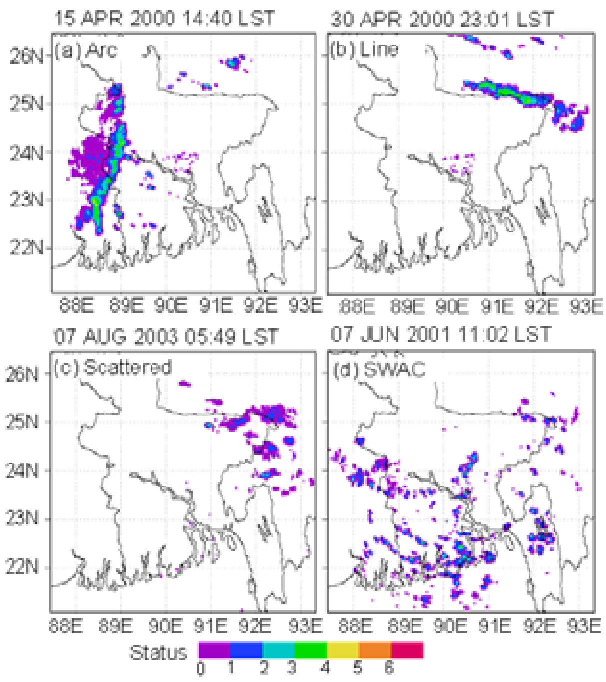

Fig. 2. Examples of (a) Arc, (b) Line, (c) Scattered type systems and (d) SWAC.

3. Results and Discussion

The detail statistics of Arc, Line and Scattered type systems developed in and around Bangladesh during the analysis period is shown in Table 1. The numbers of Arc, Line and Scattered type systems are 230, 117 and 442 respectively during the analysis period.

Table 1. Different type of systems developed in and around Bangladesh.

Month	Type of systems			PPI
	Arc	Line	Scattered	Scans
April	64	28	33	12717
May	96	27	47	16405
June	42	31	123	22413
July	21	12	114	21004
August	5	14	82	13446
September	2	5	43	5688
Total	230	117	442	91673

Figure 3 shows the dominant month for Arc, Line and Scattered type systems during 2000-2005. The total percentage of each type system is considered to be 100%. The highest frequency of Arc, Line and Scattered type system is found in May (41.7%), June (26.5%) and June (27.8%) respectively. Arc type system (ATS) started to develop from the beginning of April and become maximum in May after that started to decrease significantly. About 70% of ATS is developed in April and May. Line type system (LTS) has large contribution in April, May and June after that frequency reduces. The frequency of Scattered type system (STS) is small in April and May, and become maximum in June and then it started to decrease from July. About 70% of STS is developed in June, July and August which are monsoon months.

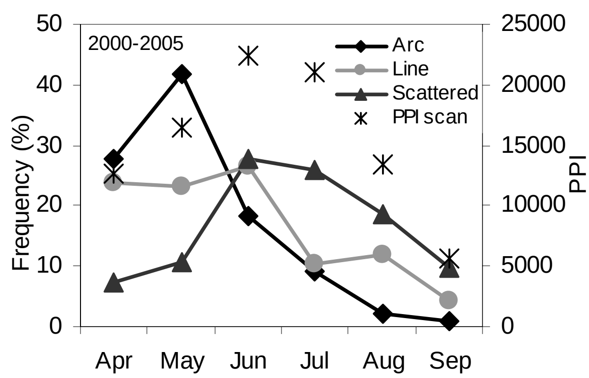

Fig. 3. Monthly frequency distribution of Arc, Line and Scattered type systems. The total percentage of each type system is considered to be 100%.

The seasonal frequency for Arc, Line and Scattered type systems is shown in Fig. 4. ATSs dominate in pre-monsoon period and STSs in monsoon period. In this calculation, frequency of SWAC is included. In pre-monsoon, the frequency of ATS is 69.3%. In monsoon, the frequency of STS is 81.9%. LTS has almost equal contribution to the number in both periods.

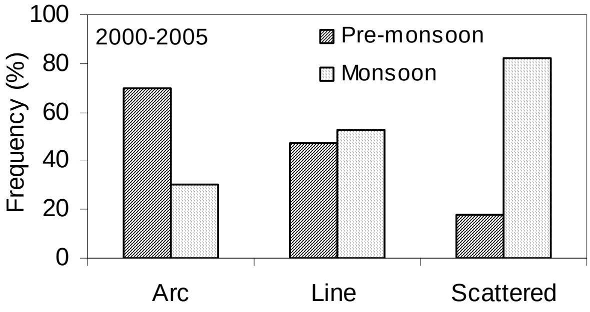

Fig. 4. Seasonal frequency for Arc, Line and Scattered type systems from 2000-2005.

Frequency of SS, MS and LS is shown in Fig. 5. The SS is dominated in April and May. The highest frequency of SS is 12.2% in May. The LS is dominated in monsoon months from June to September. The maximum frequency of LS is 12.5% in June. The MS is dominated in May and has frequency of 6.1%. Hence it is clear that small systems dominate in pre-monsoon period and large systems in monsoon period.

Distribution of the propagation speed and direction of different type systems in different seasons is shown in Fig. 6. Most of the pre-monsoon systems propagate toward southeast. Monsoon systems propagate toward northeast or northwest including southeast. Few exceptions are observed during pre-monsoon and monsoon periods. Usually the ATSs move southeastward. All the pre-monsoon systems are moving faster than monsoon systems. This is consistent with the result of Islam et al. (2004) who analyzed radar data for the year 2000. The average speed of systems in pre-monsoon and monsoon is 10.2 m/s and 6.3 m/s respectively.

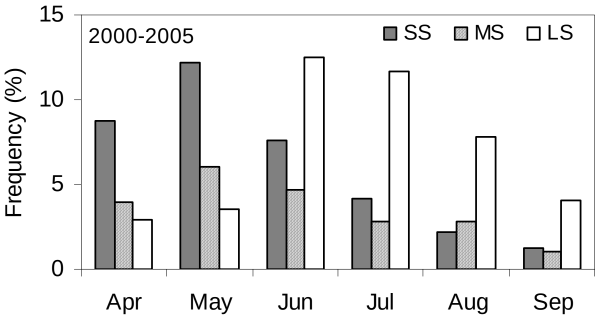

Fig. 5. Frequency of SS (small systems), MS (medium systems) and LS (large systems) during the analysis periods from 2000 to 2005. SWAC are included in LS.

The average speed, horizontal length and approximate lifetime of Arc, Line and Scattered type systems are about 11.0, 7.1 and 5.8 m/s, 185, 184 and 268 km, and 4.3, 4.0 and 4.8 hr respectively. It is clear that ATSs are moving faster compared to other types whereas STSs are slower. The horizontal length and lifetime of the systems are large for Scattered type compared to others, as expected. In this analysis the SWAC are not included. Some of this type of systems persisted long time even one day or more. Doswell et al. (1996) mentioned that the total precipitation at any point is directly proportional to the duration of rainfall and many researchers (Lopez, 1976; Houze and Cheng, 1977; Cheng and Houze, 1979) showed that rainfall is also related with the coverage of large precipitable area. Therefore, STSs contribute large amount of rainfall in this region.

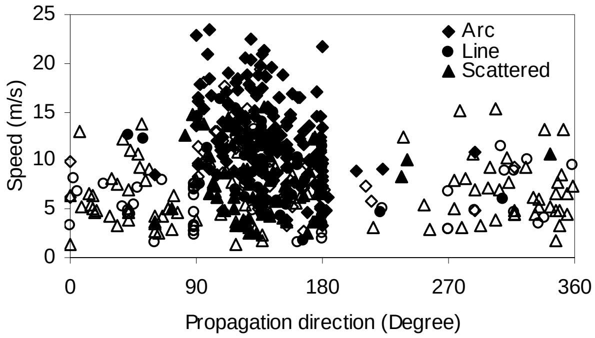

Fig. 6. Speed and direction of movement of different type of systems (zero speeded systems and SWAC systems are not included). Solid symbols represent pre-monsoon and open symbols represent monsoon systems.

Frequency of stationary, slow, fast moving systems and SWAC is shown in Fig. 7. In this analysis, SWAC are included to the entire population of the systems in different periods. From the PPI scans it is found that most of the SWAC are slowly moving in the northeast or northwest direction. Therefore SWAC are the part of the stationary or slow moving group. Fast moving systems are dominated in pre-monsoon months and have the highest frequency of 15.5 % in May. The occurrence of slow and stationary systems is large in monsoon period compared to pre-monsoon period. From the time series of PPI (not shown), it is clear that the SWAC is composed of a number of small individual convections that is growing and decaying frequently. Small Line type or Arc type systems may persist within SWAC in a random orientation.

According to the size and speed of the systems, large and stationary or slow moving systems dominated in monsoon while small and fast moving systems dominated in pre-monsoon. In monsoon the average humidity is high compared to pre-monsoon (not shown). In monsoon small instability is sufficient to develop a system whereas large instability is required to organize a system in pre-monsoon.

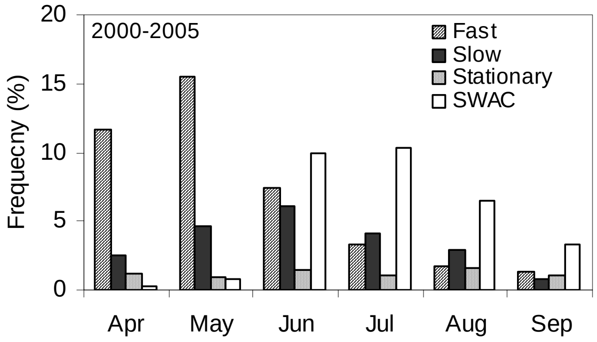

Fig. 7. Frequency of stationary, slow, fast moving systems and SWAC from 2000 to 2005. SWAC are included separately in this analysis.

4. Conclusions

Bangladesh Meteorological Department radar data of 6 years is used to classify the precipitation systems into Arc, Line and Scattered type and to study their characteristics. Scattered type systems dominate in monsoon. Monsoon systems are long and stationary or slow moving. On the other hand, Arc type systems dominate in pre-monsoon. Pre-monsoon systems are small and fast moving. Line type system has almost equal frequency in both periods. In Bangladesh, Scattered and Arc type system mainly contribute to the monsoon and pre-monsoon rainfall respectively. SWAC is considered one of the characteristics of monsoon precipitation in this area.

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