Journal of Science and Technology, 3(2): 471-479, July 2013

CHARACTERISTICS OF SUMMER MONSOON RAINFALL OVER SOUTH ASIA USING TRMM DATA

M. D. I. BHUYAN[*1], T. H. BHUIYAN[2], J. ISLAM[1], CHOUDHURY WAHID[3] and S. B. FARUQUE[2]

[1]Department of Physics, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh; [2]Department of Physics, Shahjalal University of Science & Technology, Sylhet, Bangladesh; [3]Department of Computer Science, Metropolitan University, Sylhet, Bangladesh

Abstract

The changes of South Asian Summer Monsoon (SASM) rainfall and its features are assessed using Tropical Rainfall Measuring Mission (TRMM) rainfall data for the period of 2001–2010. During 2001–2010, SASM exhibits multi-year variations, with an overall increasing trend in South-West, North-West and North-East parts of South Asia (SA) from 2001 to 2010, followed by a decreasing trend in South-East part of SA but the overall trend was positive. One of the important results in our work is that rainfall in and around Cherapuji decreasing during summer monsoon (SM) period. Furthermore, within ten years, eight out of ten maximum rainfall zones were over the Bay of Bengal near coastal part of Myanmar and the maximum rainfall zone shifted to West. According to TRMM data, it is seen that July was the maximum monsoon rainfall month and September was the minimum rainfall month. More specifically rainfall rate was high in 5th and 9th weeks of summer monsoon i.e. June, July, August and September (JJAS). This study revealed that the mean value of average daily rainfall was 5.804mm in the summer monsoon season. Amount of day time rainfall was greater than night time rainfall within these periods and maximum amount of rainfall at noon (6 GMT) to afternoon (12GMT).

Key Words: Monsoon, Diurnal variation, ENSO, Precipitation.

Introduction

South Asia is one of the regions of the heaviest rainfall in the world. Agriculture is the backbone of the Economy, which mainly dependent on monsoon rainfall. In this paper, our area of interest is between 65°E-96°E and 6°N-36°N i.e., most parts of South Asia. These regions consist also slight parts of East Asia. Based on spatial coherence of seasonal rainfall, the South Asian Monsoon (SAM) region includes parts of the Arabian Sea, the Indian continent and the North Bay of Bengal (Goswami et al., 1999). The conventional definition of the SAM season to be between June 1 and September 30 (JJAS) is arbitrary but an objective definition of the exact SAM season has been lacking. More specifically the time of this season is called South Asian Summer Monsoon (SASM) period. Recent years, SASM 'onset' takes place significantly earlier than June 1 while 'withdrawal' can take place weeks after September 30. South Asia is a very unique area with complex topography. It ranges from zero meters elevation from sea level in the south to more than 5500 meters from sea level in the north. So in terms of topography playing a role in climate and weather, this region of the world is where we expect to see a large impact.

[*] Author for Correspondence: didar_bhuiyan@yahoo.com

Asian monsoon plays a big role in the global climate system and influences most of the tropics and subtropics of the Eastern Hemisphere (Webster et al., 1998). There is also a sign that the monsoon may influence the atmospheric circulation in the extra-tropics. Summer monsoon of this region shows a pronounced variability on a wide range of time scales from intra-seasonal to inter-annual and inter-decadal (Chang and Krishnamurti, 1987; Fein and Stephens, 1987; Webster et al., 1998). Inter-annual variability in the rainfall intensity during the Summer Monsoon Season (SMS) over South Asia (SA) has significant economic and social consequences (Parthasarathy et al., 1988; Gadgil, 1996; Webster et al., 1998). If the monsoon is strong then result is floods, whereas weak monsoons can result droughts, thus affecting living conditions and the economy of this densely populated region. Therefore, the analysis of the previous rainfall pattern and the correct long term prediction of monsoon rainfall are very important for this region. The region's economy largely depends upon agriculture, so changes in the path and strength of the monsoon can be devastating. SASM is critical to agriculture in Nepal, Pakistan, India and Bangladesh- could be weakened and delayed due to increasing temperature in the future, according to a recent study (Diffenbaugh, 2009).

More than 22% of the world population lives in this part of the world and they depend inextricably on the SASM, which contributes as much as 75% of the total annual rainfall multiple SM in major parts of the region and produce almost 90% of India's water supply. (Dhar, O.N, and S. Nandargi, 2003). The major component of the water cycle is precipitation and precipitation is responsible for depositing the fresh water on the planet. Approximately 505,000 cubic kilometers (121,000 cu mi) of it over the oceans (Chowdhury, 2005). Intergovernmental Panel on Climate Change (IPCC) shows that trends of global precipitation were positive throughout the century. However, trends vary with region to region and season to season. In our work we try to show the trends of rainfall of SA in the past decade.

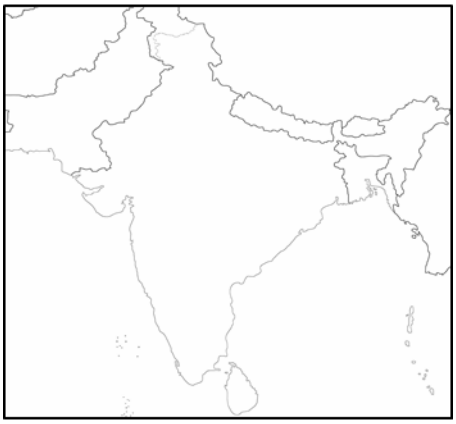

Fig. 1: Area of interest

The year to year variation of the Asian monsoon is one of the strongest signals of the earth's climate variability. Its interaction with ENSO has been of great interest to the climate research community. For developing monsoon prediction, lots of studies have focused on the relationships the monsoon and the major climate signal, i.e. EL Nino- Southern Oscillation (ENSO). Some of these studies (Webster and Yang, 1992); (Ju and Slingo, 1995); (Lau and Bua, 1998) suggested that ENSO may have an influence on the inter-annual variability of the Asian summer monsoon. In this work we try to feature summer monsoon rainfall (SMR) trend, pattern and characteristics over South Asia during 2001-2010 periods. In this study we have also summarized Diurnal rainfall variation.

Materials and Methods

The TRMM 3B42 (V6) 3-hourly 0.25° x 0.25° merged TRMM, the TRMM 3B42 (V6) daily 0.25° x 0.25° merged TRMM, the TRMM 3B43 (V6) monthly 0.25° × 0.25° merged TRMM were used in this analysis. Four months (June –September) in each year from 2001 to 2010 were used in this analysis. The study was South Asia and its adjacent areas (65°E-96°E and 6°N-36°N).

Results and Discussion

In this paper, the variations of rainfall and rainfall feature of South Asian Summer Monsoon (SASM) from 2001 to 2010 were investigated using TRMM. The main contribution of this study is to provide a full observational picture of the yearly changes of SASM rainfall and its features across the previous decade.

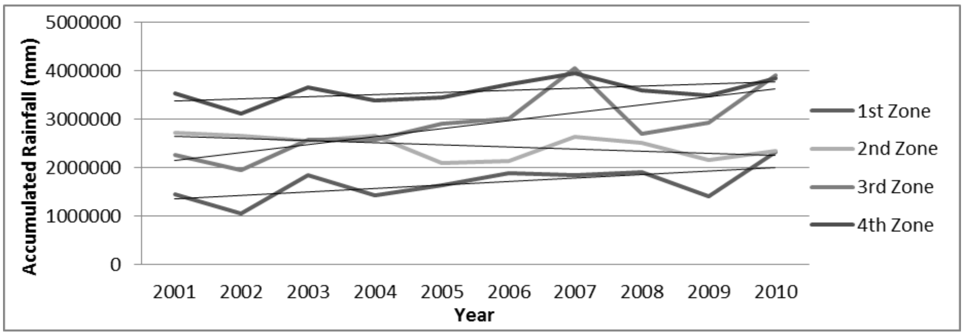

Fig. 2: Climatology of four zones from 2001 to 2010.

During 2001–2010, SASM exhibits multi-year variations, with an increasing trend in South-West i.e. area between 6°N-21°N and 65°E-81°E (3rd zone), North-West i.e. area between 21°N-36°N and 65°E-81°E (1st zone) and South-East i.e. area between 6°N-21°N and 81°E-96°E (4th zone) parts of South Asia (SA) from 2001 to 2010, followed by a decreasing trend in North-East i.e. area between 21°N-36°N and 81°E-96°E (2nd zone) part of SA shown in Fig.2 but the overall trend was positive shown in Fig.3. These four i.e. 1st, 2nd, 3rd and 4th zones received on average

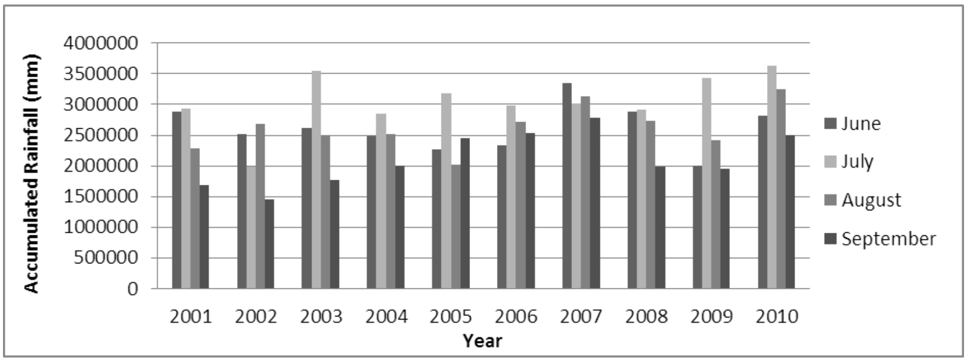

Fig. 3: Monthly rainfall variation over South Asian region from 2001 to 2010.

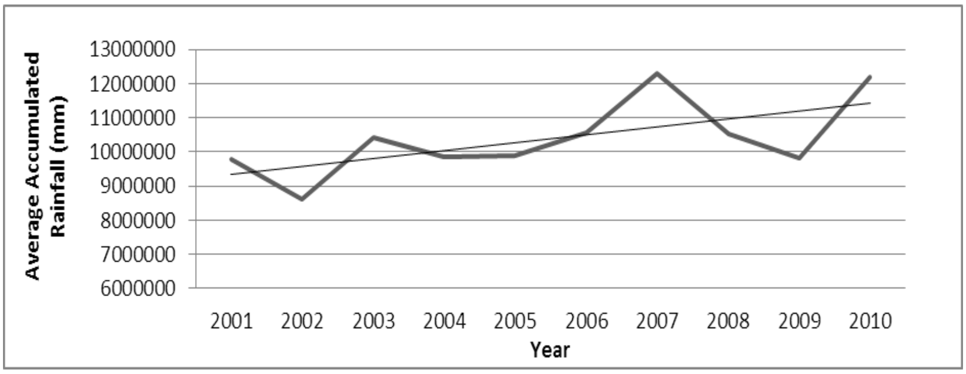

Fig. 4. Yearly rainfall variations over South Asia.

16%, 23%, 27% and 34% of total monsoon rainfall respectively in every year (Fig. 5). Moreover, in this paper we try to investigate rainfall trends of the area between 91°E-92°E and 25°N-25.75°N which consist the world highest rainfall zone i.e. Cherrapunji and also consist Mawsynram. Normally ground rainfall was higher in these areas compared to other area in SA. It is seen that in these areas the overall trend of rainfall was decreasing during 2001-2010 summer monsoon period followed by a slightly increasing trend from 2005 to 2010 shown in Fig. 6.

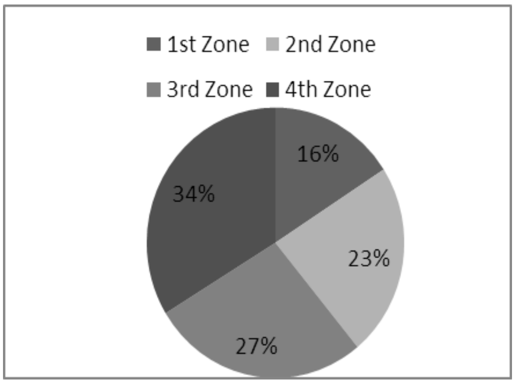

Fig. 5. Percentage of total accumulated rainfall over four zones in the last decade.

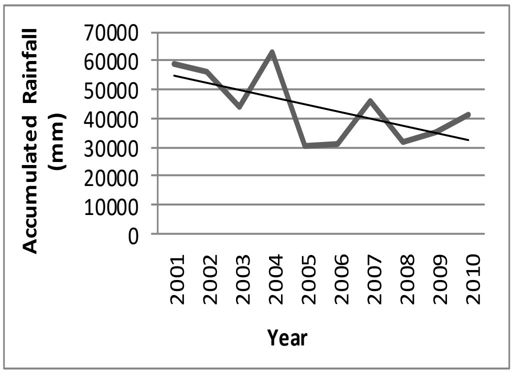

Fig. 6. Accumulated rainfall in and around Cherrapunji (area between 91E-92E and 25N-25.75N).

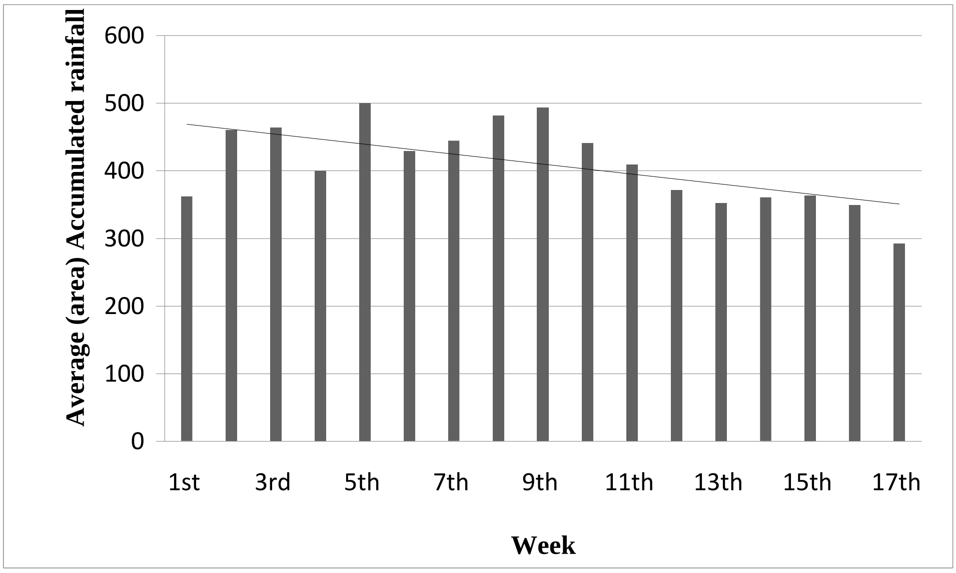

Fig.7. Ten year's average weekly rainfall over South Asia.

From this study, it is seen that July was the maximum monsoon rainfall month and September was the minimum rainfall month within the study period. More specifically rainfall rate was high in 5th and 9th weeks of summer monsoon i.e. rainfall trend was high in the middle of June and the end of July shown in Fig.7.

Table 1. Average accumulated rainfall over South Asia.

Year	Average accumulated rainfall (in mm)
2001	5.49
2002	4.83
2003	5.87
2004	5.55
2005	5.59
2006	5.86
2007	6.83
2008	5.82
2009	5.45
2010	6.79

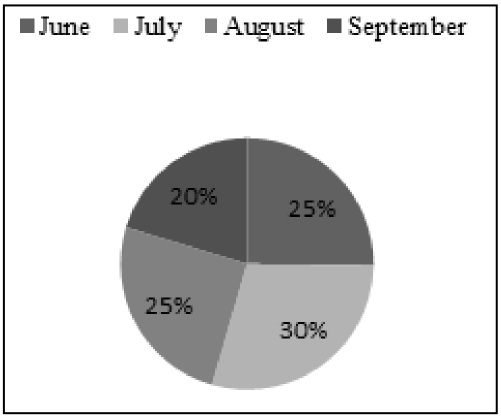

Fig. 8. Percentage of monthly rainfall contribution over South Asian region from 2001 to 2010.

From Table 1, it is also seen that 2002, 2007 and 2010 were ENSO years within these ten years. The monsoon year 2002 is El-Nino and 2007 and 2010 are La-Nina years but the intensity was not so strong. It is seen that the average rainfall was 3048456 mm in July which was 30% of total monsoon rainfall and the amount was 2111232 mm in September which accounts for 20% of total rainfall. The difference between the rainfall during June and August was negligible (5519 mm).

It is found that the average value of daily rainfall was 5.804 mm per (0.25° ×0 .25°) grid box in summer monsoon. In June it was 6.01 mm. During the first four years it was slightly higher than average and then next two years it was less than average. However in 2007 it was the highest (7.66 mm). In July the monthly mean value of average daily rainfall was 6.685mm. In August it was nearly similar to the average and in September it was 4.81 mm which was too less than average. That means July receives the maximum amount of rainfall. Fig. 9 shows how much rain fell over South Asia during last twelve summer monsoon season. It is observed that Cherapunji was the maximum rainfall zone (2400-3400) mm per (0.25°× 0.25°) grid box in South Asia. Coastal area near the windward side of the Western Ghats of India, in general around the border region between Kerala and Karnataka, adjacent to the Arabian Sea receive 2100-2400 mm per (0.25°× 0.25°) grid in every monsoon. Rainfall was high around the coastal areas of India (in and around Kozhikode, Mangalore, Margao, Panjim, Panvel, Navi Mumbai etc. near the Western

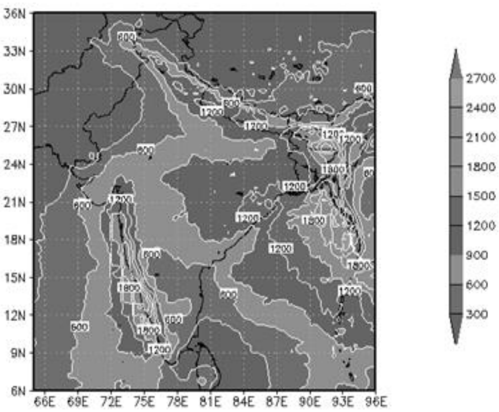

Fig. 9. Rainfall climatology (June- September) for last 10 years using TRMM (in mm)

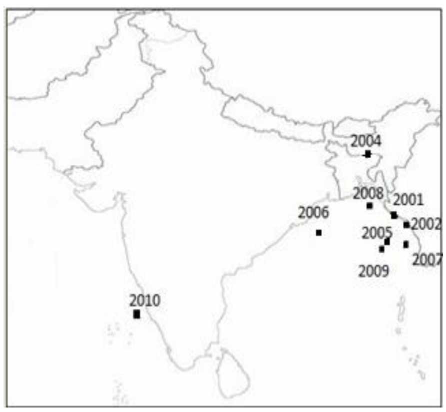

Fig. 10. Maximum Summer Monson rainfall location over South Asia from 2001 to 2010

Ghats) and adjacent areas of Arabian Sea, in and around Cherapunji and over the Bay of Bengal adjacent to the western coast of Myanmar. It is also seen that rainfall over the Bay of Bengal near coastal area of Myanmar shifted to the west during the study period. Important observation is that all the high rainfall areas were placed near a mountain range (near the Himalaya, katabatic mountain, the Western Ghats, ArakanYoma Mountains etc.) that means near to the mountain range (in windward side) rainfall rate was very high. This is we all know due to orographic effect and this type of rain is called orographic rain.

Table 2. Maximum rainfall position and amount of rainfall over South Asia.

Year	Maximum Rainfall Area	Amount of rainfall (mm)
2001	20°N,93°E	4254
2002	19°N, 93.5°E	4361
2003	20.5°N, 92.5°E	3449
2004	25°N, 91.5°E	3878
2005	17.75°N, 92.5°E	3164
2006	18.75°N, 87°E	3105
2007	17.5°N, 93.5°E	3790
2008	21°N, 91°E	2791
2009	17.25°N, 92.25°E	3608
2010	13°N,74.25°E	3171

In Bangladesh, Sylhet was the maximum rainfall area. This area received about 1800-2700 mm of rainfall per (0.25°× 0.25°) grid areas every monsoon year. The minimum rainfall area was Rajshahi specifically around Ishurdi. In India, western areas of Rajastan and border region (with Tibet) of Jammu and Kasmir were the minimum rainfall area in summer monsoon season. In Nepal, the area between 27.5°N-28.25°N and 84°E-84.5°E was the maximum rainfall (1200-1500mm) zone. This area consists in part of Kathmandu, Hetauda and Gurkha. In Bhutan, Indian boarder region of Sarpang was the high rainfall area. Part of Rawalpindi and Islamabad were the maximum rainfall zone in Pakistan, where on average rainfall were 600-900mm per (0.25°×0.25°) resolution and nearly zero or >50mm rain falls in North-West part of this country. In Sri Lanka in and around Colombo was the maximum rainfall area. This area received about 600-900mm rain per (0.25°× 0.25°) grid area. Fig.11 and Table 2, represents the maximum monsoon rainfall location over South Asia from 2001 to 2010. In SA from 2001 to 2010, we see that maximum location situated over the Bay of Bengal near to the western coast of Myanmar and surface rainfall was highest in and around Cherapunji.

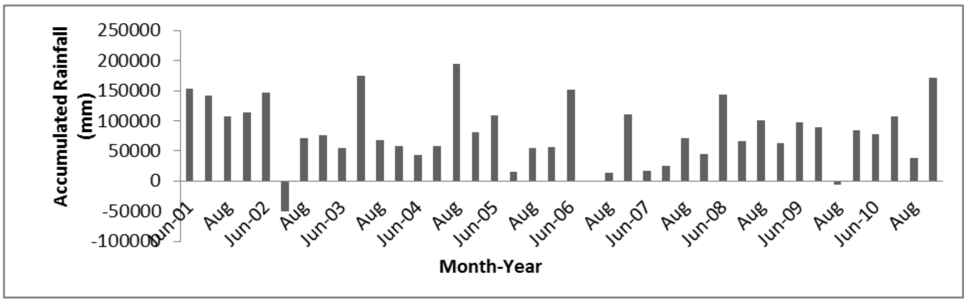

Fig. 11: Day-Night Rainfall Difference. (Difference = day rainfall – night rainfall)

In this study daytime (52%) rainfall was observed to be higher than night time (48%) rainfall [Fig.12(i)]. It is seen that at 06Z–09Z or 06GMT–09GMT (middle of the day) rainfall was maximum (14.3%) shown in Fig. 12(ii). The second highest amount of rainfall was observed at 09Z–12Z (13.9%). From 21Z to 00Z (late night) the amount of rainfall was 12.6% and during 00Z–03Z and during 15Z–18Z the rainfall was 11.6% of the total.

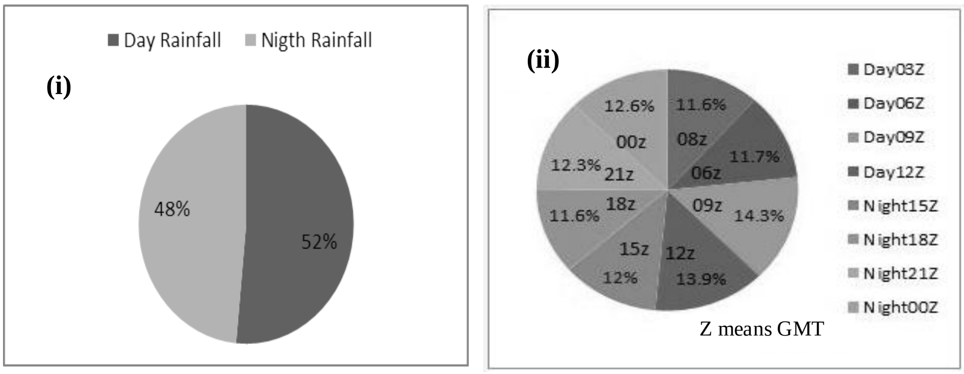

Fig. 12. Percentage of day-night and 3-hourly rainfall contribution in monsoon season over South Asia using last ten years data i. Day-Night ii. 3-hourly

Conclusion

In this paper we have investigated the SASM rainfall distribution and its features. Here we have found an overall increasing trend of rainfall in the South-West, North-West and North-East parts of South Asia (SA) whereas a decreasing trend in South-East part of SA with overall an increasing trend. On the other hand, rainfall in and around Cherapunji is found to decrease during summer monsoon (SM) period. Maximum rainfall zones are found over the Bay of Bengal, near the coastal part of Myanmar and maximum rainfall zone have a trend to shift towards West. TRMM data analysis reveals minimum rainfall in September whereas maximum monsoon rainfall in July, particularly in 5^{th} and 9^{th} weeks of the summer monsoon. At summer monsoon, the mean value of average daily rainfall is found 5.804 mm with higher rainfall at day time compared to night time. The maximum amount of rainfall is found at noon to afternoon.

References

Chang CP and Krishnamurti TN eds. (1987). “Monsoon Meteorology”. Oxford University Press: Oxford.

Chowdhury's Guide to Planet Earth (2005). "The Water Cycle". WestEd.

Diffenbaugh (2009), An associate professor of earth and atmospheric sciences and interim director of the Purdue Climate Change Research Center, “Purdue study projects weakened monsoon season in South Asia”. Source: Noah Diffenbaugh, (765) 490-7288. Writer: Elizabeth K. Gardner, (765) 494-2081.

Dhar, O. N., and S. Nandargi (2003). “Hydrometeorological aspects of floods in India”, Nat. Hazards, **28**: 1-33.

Fein JS and Stephens PL eds. (1987). Monsoons. John Wiley: New York.

Gadgil S. (1996). "Climate change and agriculture - an Indian perspective. In Climate Variability and Agriculture”, Abool YR, Gadgil S, Pant GB (eds). Narosa: New Delhi, India; 1-18.

Goswami, B. N., V. Krishnamurthy and H. Annamalai (1999). " A broad scale circulation index for inter-annual variability of the Indian summer monsoon", Q. J. R. Meteorol. Soc., **125**: 611-633.

Ju J. and Slingo JM. (1995). "The Asian summer monsoon and ENSO". Quarterly Journal of the Royal Meteorological Society, **122**: 1133-1168.

Lau, K-M., and W. Bua, (1998) " Mechanism of monsoon-Southern Oscillation coupling: insights from GCM experiments". Climate Dynamics, **14**: 759-779.

Parthasarathy B, Munot AA and Kothawale DR. (1988)." Regression model for estimation of Indian food grain production from Indian summer rainfall". Agricultural and Forecasting Meteorology, **42**: 167-182.

Webster P. J and Yang S. (1992). "Monsoon and ENSO: selectively interactive systems". Quarterly Journal of the Royal Meteorological Society, **118**: 877-926.

Webster P. J, Magana VO, Palmer TN, Shukla J, Tomas RA, Yanai M and Yasunari T. (1998). "Monsoons: processes, predictability, and the prospects for prediction". Journal of Geophysical Research, **103**: 14451-14 510.