

A STUDY ON SUMMER MONSOON SEASON AND RAINFALL CHARACTERISTICS IN SUMMER MONSOON SEASON OVER SOUTHERN VIETNAM IN 1981-2014 PERIOD

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ABSTRACT: This study determines the summer monsoon season over Southern Vietnam in 1981-2014 period by using observed daily rain-gauge data and reanalyzed daily 850 hPa wind data. The results show that the mean onset and retreat dates of summer monsoon over Southern Vietnam occur on May 15 and October 13, with standard deviations of 14.12 and 13.55 days, respectively. The results also show that the onset and retreat dates tend to precede in the recent years. In summer monsoon period, the values of RX1day and RX5day are high in Rach Gia and Ca Mau but low in Can Tho, CDD of all stations are low. In all stations, the values of extreme rainfall indices in 1998-2014 period are higher compared to those in 1981-1997 period.

Keywords: Summer monsoon, rainfall indices, Southern Vietnam.

INTRODUCTION

Summer monsoon is marked by drastic changes from dry season to rainy season, providing a significant amount of rainfall in many regions. The changes of the onset and retreat of summer monsoon and extreme rainfall phenomena lead to the changes in water resources which directly significantly affect agriculture, forestry, fishing, farming, and traffic...

Nowadays, studies on summer monsoon are often based on rainfall index [1-4], wind index [5], or OLR and wind combined index [6]. Zhang et al., (2002) showed that the mean onset date of summer monsoon over Indochina in 1951-1996 period was on May 5. Wang et al., (2002) showed that summer monsoon rainfall occurred over Indochina in the early May (pentad 25-pentad 26) and over the East Vietnam Sea in the middle May (pentad 27-pentad 28). Wang et al., (2004) used the zonal

wind index at 850 hPa level from NCEP/NCAR to calculate the monsoon onset over the East Vietnam Sea. They pointed out that the onset occurred in middle May (pentad 28). Wang et al., (2004) and Kajikawa and Wang (2012) revealed that the summer monsoon onset date in 1994-2008 period occurred 3 pentads earlier than that in 1979-1993 period. The retreat date of two periods both occurred around middle October. Prasad et al., (2005) showed that summer monsoon season over Indian in 1958-2001 period began in late May and June, ended in late September and October. By combining OLR and wind, Wei-Dong et al., (2012) indicated that the mean onset date over the East Vietnam Sea in 1979-1995 period was May 6 with standard deviation of 13 days.

Southern Vietnam is one of the most clearly effective areas of summer monsoon. In addition, water resources in this area strongly depend on summer monsoon rainfall.

Therefore, there are several studies on summer monsoon over Southern Vietnam related to onset date [7], relationship between rainfall and ENSO as well as simulated large-scale circulation in summer monsoon pre-onset [8, 9]. The results of Thanh et al., (2010) showed that the mean summer monsoon onset date over Southern Vietnam during 1979-2004 period occurred on May 12 with standard deviation of 11.6 days. Besides, the rainy onset date in Southern Vietnam in El Niño years occurred earlier than in La Niña years [10].

Overall, a lot of studies on summer monsoon onset date have been carried out but those on summer monsoon retreat date are still limited, especially on extreme rainfall indices in summer monsoon season. Thus, in this study, the changes of summer monsoon onset and retreat dates over Southern Vietnam during

1981-2014 period are examined as well as the changes of extreme rainfall indices in summer monsoon season are also carried out.

DATA AND METHODOLOGY

Data

Observed daily rainfall of 4 stations in Southern Vietnam during 1981-2014 period has been used in this study. In order to avoid possible biases, only the year (month) having more than 330 days (25 days) is included in rainfall data series. The NCEP/NCAR reanalyzed daily 850 hPa wind data in $2.5^\circ \times 2.5^\circ$ grid box is used to calculate the wind index for a specific year. It is defined as daily value of 850 hPa zonal wind speed averaged on the domain extending for about 9°N - 11.5°N and 104.5°E - 107°E . List of stations over Southern Vietnam is described in table 1.

Table 1. Stations in the Southern Vietnam

No.	Stations	Lon.	Lat.	No.	Stations	Lon.	Lat.
1	Tay Ninh	106.12	11.33	3	Rach Gia	105.07	10.00
2	Can Tho	105.77	10.03	4	Ca Mau	105.15	9.14

Methodology

Criteria for summer monsoon onset and retreat dates

The onset (retreat) date of summer monsoon for a specific year over Southern Vietnam is determined by 5-day running rainfall series and the 850 hPa zonal wind index. The onset (retreat) date must satisfy the two following conditions: The onset (retreat) date is the first day out of five continuous days having total 5 day running rainfall greater than

5 mm. The average daily wind index at 850 hPa level is greater than 0.5 m/s for 5 continuous days for onset (retreat) date forward (backward) [11]. The length of summer monsoon season is the period from the onset date to the retreat date of summer monsoon.

Extreme rainfall indices

Table 2 describes some extreme rainfall indices in this study. Except WD, the remaining indices follow Peterson et al., (2001) [12].

Table 2. The rainfall indices

No.	Indices	Definitions	Units
1	WD	Annual count of wet days (day where rainfall \geq 1mm)	day
2	PRCPTOT	Annual total precipitation in wet days	mm
3	SDII	Simple precipitation intensity index: the ratio of PRCPTOT to WD	mm/day
4	RX1day	Monthly/annual maximum 1-day precipitation	mm
5	RX5day	Monthly/annual maximum consecutive 5-day precipitation	mm
6	R50	Annual count of days where rainfall \geq 50mm	day
7	CDD	Maximum length of dry spell, maximum number of consecutive days with rainfall $<$ 1 mm	day
8	CWD	Maximum length of wet spell, maximum number of consecutive days with rainfall \geq 1 mm	day

Sen’s slope method [13] is used to estimate the trend of the onset (retreat) date of summer monsoon and rainfall indices. The non-parametric Mann-Kendall test is used to examine the trend’s statistical significance at 0.05 level [14]. Besides, in order to clarify the recent trend of summer monsoon onset (retreat) date and rainfall indices, the 1981-2014 period is divided into two equal sub-periods 1981-1997 and 1998-2014. Then, the difference of the mean onset (retreat) date and rainfall indices between two sub-periods is calculated. The Student test is used to examine these

changes with the statistical significance at 0.05 level.

RESULTS AND DISCUSSIONS

The onset and retreat dates over Southern Vietnam in 1981-2014 period

Table 3 describes the summer monsoon onset and retreat dates over Southern Vietnam during 1981-2014 period. Table 3 reveals that the mean summer monsoon onset and retreat dates are May 15 and October 13 with standard deviations of 14.12 days and 13.55 days, respectively.

Table 3. The summer monsoon onset and retreat dates over Southern Vietnam during 1981-2014 period

Years	Onset dates	Retreat dates	Years	Onset dates	Retreat dates
1981	16-May	19-Oct	1998	26-May	19-Oct
1982	02-Jun	22-Oct	1999	11-May	08-Nov
1983	22-May	15-Oct	2000	08-May	17-Oct
1984	24-May	17-Oct	2001	11-May	11-Oct
1985	25-Apr	06-Oct	2002	24-May	25-Sep
1986	16-May	16-Oct	2003	21-May	01-Oct
1987	11-Jun	18-Sep	2004	14-May	19-Sep
1988	04-May	29-Sep	2005	07-May	08-Oct
1989	16-May	15-Oct	2006	16-May	15-Oct
1990	20-May	20-Oct	2007	07-May	06-Oct
1991	09-Jun	13-Oct	2008	01-May	02-Nov
1992	18-May	21-Sep	2009	25-May	18-Nov
1993	05-Jun	26-Sep	2010	05-May	16-Nov
1994	08-May	30-Sep	2011	26-May	14-Oct
1995	12-May	12-Oct	2012	25-Apr	09-Oct
1996	07-May	04-Nov	2013	07-Jun	11-Oct
1997	16-May	06-Nov	2014	12-May	11-Oct
			Mean	15-May	13-Oct
			STDV	14.12	13.55

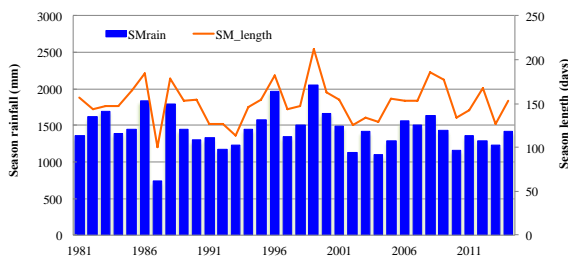


Fig. 1. Total annual summer monsoon rainfall and summer monsoon season’s length during 1981-2014 period

The summer monsoon onset and retreat dates tend to occur earlier in the recent years

with the Sen coefficients of 3.3 days and 1.76 days per decade. However, all tendency values are statistically non-significant at 0.05 level. The summer monsoon onset and retreat dates in 1998-2014 period occur earlier respectively about 6 days and 1 day compared to 1981-1997 period.

The variation of total annual summer monsoon rainfall (SM rain) and summer monsoon season’s length (SM_length) over Southern Vietnam during 1981-2014 period are plotted in fig. 1. In general, total summer monsoon rainfall changes from less than 800 mm (in 1987) to more than 2000 mm (in 1999).

The shortest summer monsoon season's length and the smallest total rainfall occur in 1987 in accordance with El Niño phenomenon. In contrast, the longest summer monsoon season's length and the highest total rainfall are observed in 1999 in agreement with La Niña phenomenon. These results are consistent with the study of Thuan et al., (2007). The total rainfall in summer monsoon season is highly correlated with the length of summer monsoon season with correlation coefficient of 0.83. The averaged summer monsoon season's length

over Southern Vietnam in 1981-2014 period is 152 days. Besides, the results also show that the onset and retreat dates of summer monsoon are significantly correlated with total summer monsoon rainfall with coefficients of -0.55 and 0.81, respectively.

Changes in extreme rainfall indices

Figure 2 illustrates some statistical characteristics of extreme rainfall indices in summer monsoon season over Southern Vietnam during 1981-2014 period.

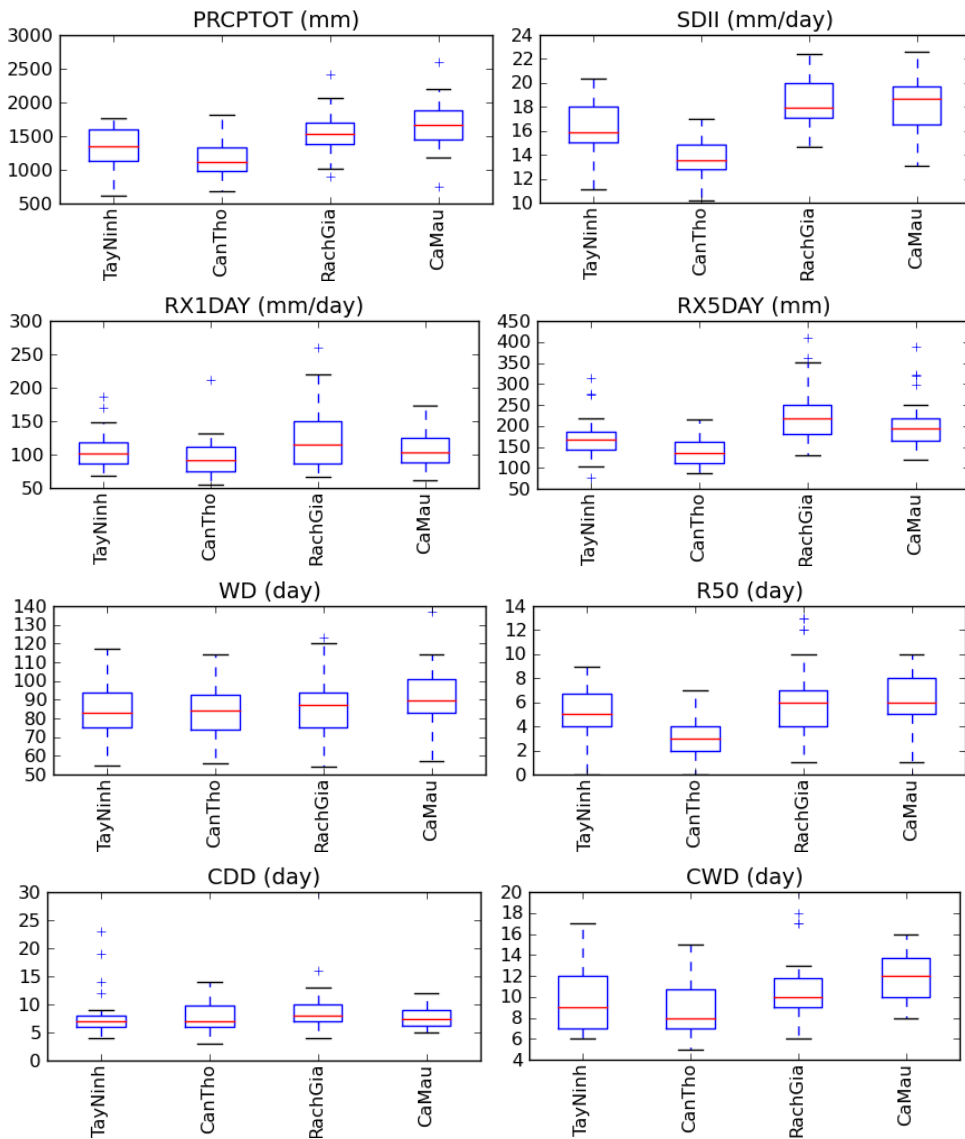


Fig. 2. Box plots of extreme rainfall indices in summer monsoon season at each station during 1981-2014 period

It can be seen that PRCPTOT and SDII are high at Rach Gia and Ca Mau but low at Can Tho. The highest value of PRCPTOT is 2597.2 mm at Rach Gia recorded in 1999 while the lowest one is 612.9 mm recorded at Tay Ninh in 1987. The maximum value of RX1day is 260.5 mm in 1982 and that of RX5 day is 410.2 mm in 2003 at Rach Gia. WD varies

from 75 to 100 days. WD can reach 137 days at Ca Mau in 1999. R50 varies from 2 to 8 days at 4 stations. The highest value of R50 is 13 days in 1999 at Rach Gia. The averaged value of CDD is 7 days. Meanwhile, CWD strongly changes among years and stations. CWD values at Can Tho are the lowest values compared to other stations.

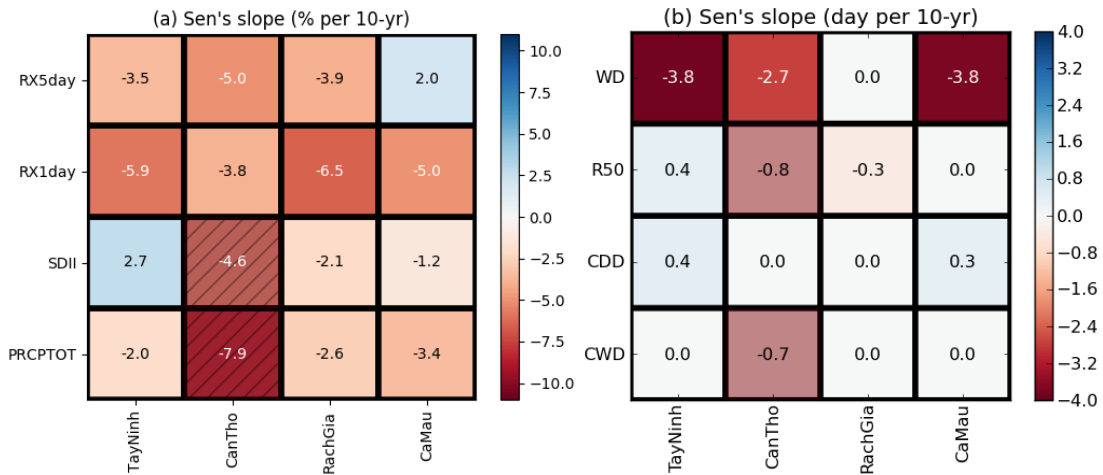


Fig. 3. Sen's slope of rainfall indices at each station during 1981-2014 period. Unit: %/10 year (a) and day/10 year (b). The hatched pattern indicates the trend is statistically significant at 0.05 level

Fig. 3 indicates the trend of extreme rainfall indices in summer monsoon season represented by Sen coefficient. The trends of RX1day, RX5day, SDII, PRCPTOT decrease at most of stations except for RX5day at Ca Mau and SDII

at Tay Ninh. The decreasing trends of SDII and PRCPTOT satisfy statistical significance at 0.05 level. In almost all the stations, WD shows a significantly downward tendency while R50, CDD, CWD show little changes.

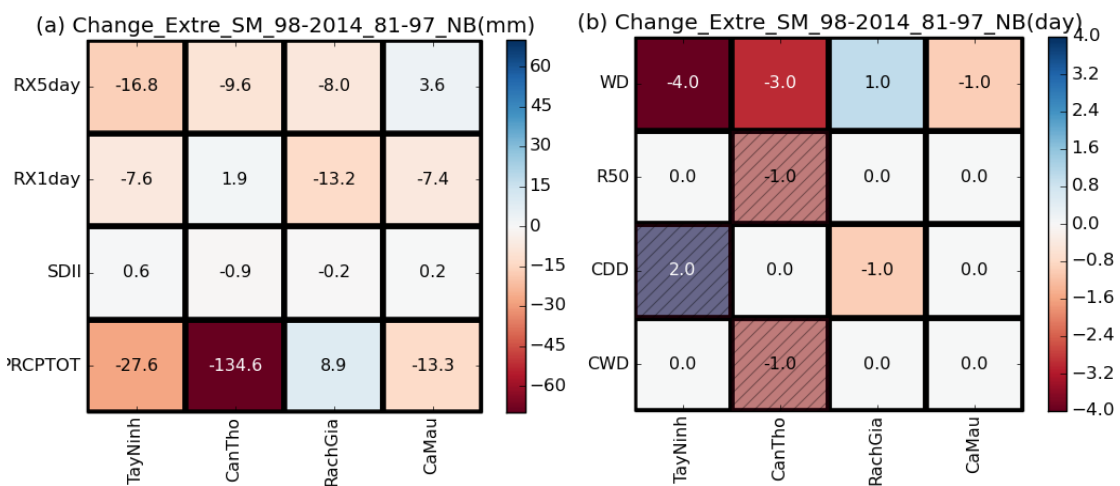


Fig. 4. The differences of rainfall indices between two sub-periods 1998-2014 and 1981-1997 over Southern Vietnam. The hatched pattern indicates the trend is statistically significant at 0.05 level

Fig. 4 indicates the differences of rainfall indices in summer monsoon season between two sub-periods 1998-2014 and 1981-1997 over Southern Vietnam. In summer monsoon season, CDD at Tay Ninh in 1998-2014 period is higher than that in 1981-1997 period (2 days/year). Meanwhile, R50 and CWD at Can Tho in the later period are lower than those of the previous one and both have statistical significance at 0.05 level. In almost all the stations, RX5day, RX1day, SDII, PRCPTOT and WD in the later period are lower than those in the previous one.

CONCLUSIONS

In this study, the observed daily rain-gauge data and reanalyzed daily 850 hPa wind data are used to determine the onset and retreat dates of summer monsoon over Southern Vietnam during 1981-2014 period. The results show that the mean onset and retreat dates of summer monsoon over Southern Vietnam occur on May 15 and October 13 with standard deviations of 14.12 and 13.55 days, respectively. The results also show that the onset and retreat dates tend to precede in the recent years. The onset date, retreat date and length of summer monsoon season are significantly correlated with the total summer monsoon rainfall with the coefficients of -0.55, 0.81 and 0.83, respectively.

In the summer monsoon period, values of RX1day and RX5day are high in Rach Gia and Ca Mau but low in Can Tho, CDD of all stations are low. The values of extreme rainfall indices in 1998-2014 period are higher than those in 1981-1997 period at all stations.

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