Regional Characteristics of the Summer Monsoon Onset in the Indochina Peninsula

Takashi EGUCHI
(*Department of Humanities, Faculty of Humanities and Economics*)

Abstract

The purpose of this paper is to clarify the regional characteristics of the summer monsoon onset in the western part of the Indochina Peninsula.

The onset of the Indochina summer monsoon differs regionally along the west coast whose boundaries are located around 17°N and 19°N. The onset connected with the tropical cyclone represents 50% of all onsets south of 19°N and tropical cyclone originating in the Bay of Bengal is an important factor on the onset of the Indochina summer monsoon. The onset date north of 19°N along the west coast and that of the northernmost region of Myanmar correspond closely with those of Kerala, the southern tip of India.

The precipitation distribution changes before, at and after the onset. Before the onset of the Indochina summer monsoon, precipitation is more abundant in Thailand than along the west coast. During the period from the first onset of the Indochina summer monsoon to the onset of the summer monsoon in the whole Indochina Peninsula, heavy rains occur around ITCZ and the regional differences in precipitation are relatively small. After the onset of the summer monsoon in the whole Indochina Peninsula, precipitation increases in the windward regions against the southwesterlies but decreases in the leeward basins and plains against the southwesterlies. The regional difference in precipitation becomes large.

Key word : Summer monsoon onset, Interannual variation, The Indochina Peninsula

I. Introduction

The Indochina Peninsula is located at the central part of the Monsoon Asia and also at the boundary between the subcontinent of India (or Indian Ocean) and the western Pacific. In the Indochina Peninsula, the onset of summer monsoon is early and the period of summer monsoon is long, comparing with the other regions of Monsoon Asia (e.g. India Meteorological Department, 1943). Therefore, the Indochina Peninsula is one of the key regions in order to clarify the Asian summer monsoon. However, the summer monsoon has been mainly studied in the subcontinent of India (e.g. Ananthakrishnan and Soman, 1988; Yasunari, 1979; Shukla, 1987) and the summer monsoon have not been fully clarified in the Indochina Peninsula. One of the reasons why the summer monsoon have not been fully clarified in the Indochina Peninsula is considered to be the large regional diversity of climate (Eguchi, 1996), because the mountainous areas are widely distributed in the Indochina Peninsula. Therefore, it is necessary to clarify the temporal changes and variations in the Indochina summer monsoon considering the relationship between climate and topography.

The purpose of this paper is to clarify the regional characteristics of summer monsoon onset in the western part of the Indochina Peninsula. Firstly, the regional characteristics of interannual variation in the onset date is analyzed. Secondarily, the regional difference in precipitation around the summer monsoon onset is clarified in relation to topography.

II. Data and method

The study area is Myanmar and Thailand, with 31 precipitation stations in Myanmar and 44 in Thailand (Fig. 1). The original precipitation data used in this study are the 10-day total precipitation data in Myanmar and the daily precipitation data in Thailand. The daily precipitation data in Thailand are compiled into 10-day total precipitation data, and the temporal and regional differences in precipitation are mainly analyzed using the 10-day total precipitation data. Each month is divided into three 10-day periods, early, mid- and last 10-day period, namely 1st to 10th, 11th to 20th and 21st and the last day of month, respectively. The precipitation data cover a period of 29 years from 1951 to 1979.

From the analysis of the Indochina summer monsoon in 1979, at the onset, precipitation increases largely along the west coast of the Indochina Peninsula and the equatorial westerlies invade over the Indochina Peninsula (Shinoda et al., 1986). He et al. (1987) and Orgill (1967) also showed that the same phenomena occurred at the onset of the Indochina summer monsoon. Therefore, in this study, the onset date of the Indochina summer monsoon is defined by the increase of precipitation along the west coast of the Indochina Peninsula and by the invasion of equatorial westerlies over the Indochina Peninsula. The wind data are derived from the Daily

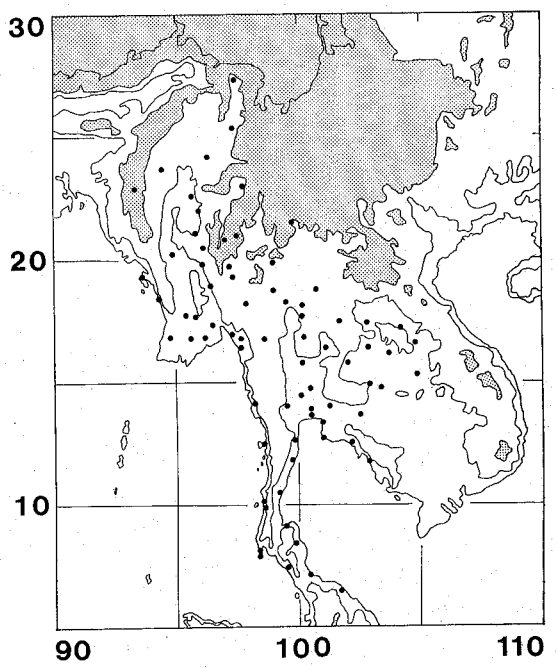


Figure 1. Location map of precipitation stations in Myanmar and Thailand. The contour lines in the figure indicate 200m, 1,000m and 3,000m, and the areas more than 1,000m are hatched.

Weather Bulletin Thailand. The onset date is defined using both precipitation and wind data for 20 years from 1960 to 1979. While, it is defined only using precipitation data for 9 years from 1951 to 1959 based on the change of precipitation distribution around the onset shown by the analysis for 20 years from 1960 to 1979.

III. Interannual variation of the summer monsoon onset

Based on the analysis of the onset of the summer monsoon over the 29 years from 1951 to 1979, the onset date differs regionally along the west coast of the Indochina Peninsula, i.e. the region between 10°N and 17°N, between 17°N and 19°N and the north of 19°N (Table 1). In

Table 1. Onset date of summer monsoon in the Indochina Peninsula and the southern tip of India.
The onset of Indochina summer monsoon is defined the monsoon westerlies in the lower toroposphere and the rainfall along the west coast of Myanmar.
SI, south Indochina (10°N-17°N); CI, Central Indochina (17°N and 19°N);
NI, north Indochina (north of 19°N)
Onset date of Indochina shows as follows;
5, May; 6, June
E, early (1-10); M, mid (11-20); L, late (21- end of the month)
For example, 5E indicates early May.
TC in the parenthesis after the onset date of Indochina indicates that the tropical cyclone or depression of the Bay of Bengal is connected to the onset of Indochina summer monsoon in the region of SI and CI for 20 years from 1960 to 1979.
Number of onset type is four, i.e. OT1 - OT4. The content of each onset type is shown in text.
The data of India are from Ananthakrishnan and Soman (1988).
SK, Onset date over south Kerala; NK, Onset date over north Kerala; IMD, Onset date for Kerala as per India Mereorological Department records.

	Indochina			India (Kerala)		
			Onset type			
	SI	CI	NI	SK	NK	IMD
1951	5L	6E	6E OT2	5/30	6/ 1	5/31
1952	5L	5L	5L OT1	5/20	6/ 2	5/30
1953	5E	5E	5M OT3	6/ 6	6/17	6/ 7
1954	5E	5M	5L OT4	5/28	6/ 1	5/31
1955	5M	5M	5L OT3	5/17	5/16	5/29
1956	5E	5E	5M OT3	5/18	5/20	5/21
1957	5L	6E	6E OT2	5/18	5/18	6/ 1
1958	5L	6E	6M OT4	6/12	6/13	6/14
1959	5L	5L	5L OT1	5/12	5/15	5/31
1960	5L	5L	5L OT1	5/14	5/15	5/14
1961	5E(TC)	5L(TC)	5L OT2	5/18	5/20	5/18
1962	5M	5L	5L OT2	5/10	5/10	5/17
1963	5L(TC)	5L(TC)	6E OT3	6/ 5	6/ 4	5/31
1964	5E(TC)	5E(TC)	6E OT3	6/ 5	6/ 4	6/ 6
1965	5L	5L	6M OT3	5/24	6/ 6	5/26
1966	5E	6E(TC)	6E OT2	5/31	5/31	5/31
1967	5M(TC)	5M(TC)	6E OT3	6/ 8	6/ 9	6/ 9
1968	6E	6E	6E OT1	6/ 8	6/ 9	6/ 8
1969	5L	5L	5L OT1	5/25	6/ 1	5/17
1970	5M(TC)	5L(TC)	5L OT2	5/25	5/26	5/25
1971	5L(TC)	5L(TC)	5L OT1	5/25	5/25	5/27
1972	5M	5L	6M OT4	6/22	6/22	6/18
1973	5E	5E	5M OT3	6/ 3	6/ 6	6/ 4
1974	5L	5L	6E OT3	5/23	5/23	5/26
1975	5L	5L	5L OT1	6/ 1	5/31	5/31
1976	5E(TC)	5L	5L OT2	5/30	5/31	5/31
1977	5M(TC)	5M(TC)	5M OT1	5/27	6/ 7	5/30
1978	5M(TC)	5M(TC)	6E OT3	5/27	5/29	5/28
1979	5M(TC)	5M(TC)	6M OT3	6/11	6/12	6/13

1979, the onset period north of 19°N is different from that south of 19°N along the west coast. While, it is the same time as that in the northernmost region of Myanmar, north of 25°N. Therefore, the onset in the northernmost region is analyzed instead of that north of 19°N along the west coast because of the insufficient of precipitation data except for 1979.

The mean onset date is mid-May and the range of onset date is from early May to early June in the region south of 17°N (Table 1). In the region between 17°N and 19°N, the mean onset date is the first half of late May and the range of onset date is from early May to early June. In the northernmost region north of 19°N, the mean onset date is in the latter half of late May and the range of onset date is mid-May to mid-June. Many authors showed that the mean onset date was mid-May (e.g. India Meteorological Department, 1943; Orgill, 1967; Tanaka, 1992; Matsumoto, 1989, 1992; Nakazawa, 1992) and this onset date corresponds to that south of 17°N of this study. Orgill (1967) also analyzed the interannual variation of the onset using the 29 years of data from 1936 to 1964, and showed that the range of the onset date was from May 1 to June 3. This range of onset date also corresponds to that south of 17°N in this study.

The northward advance of the onset is classified into four types as follows (Table 1);

Onset type 1 (OT1)

The onset occurs at the same time in the whole regions; 8 years out of 29 years from 1951 to 1979, 6 years out of 20 years from 1960 to 1979

Onset type 2 (OT2)

The first onset occurs in the region between 10°N and 17°N and the second onset occurs at the same time in the region north of 17°N; 7 years out of 29 years from 1951 to 1979, 5 years out of 20 years from 1960 to 1979

Onset type 3 (OT3)

The first onset occurs at the same time in the region south of 19°N and the second onset occurs in the region north of 19°N; 11 years out of 29 years from 1951 to 1979, 8 years out of 20 years from 1960 to 1979

Onset type 4 (OT4)

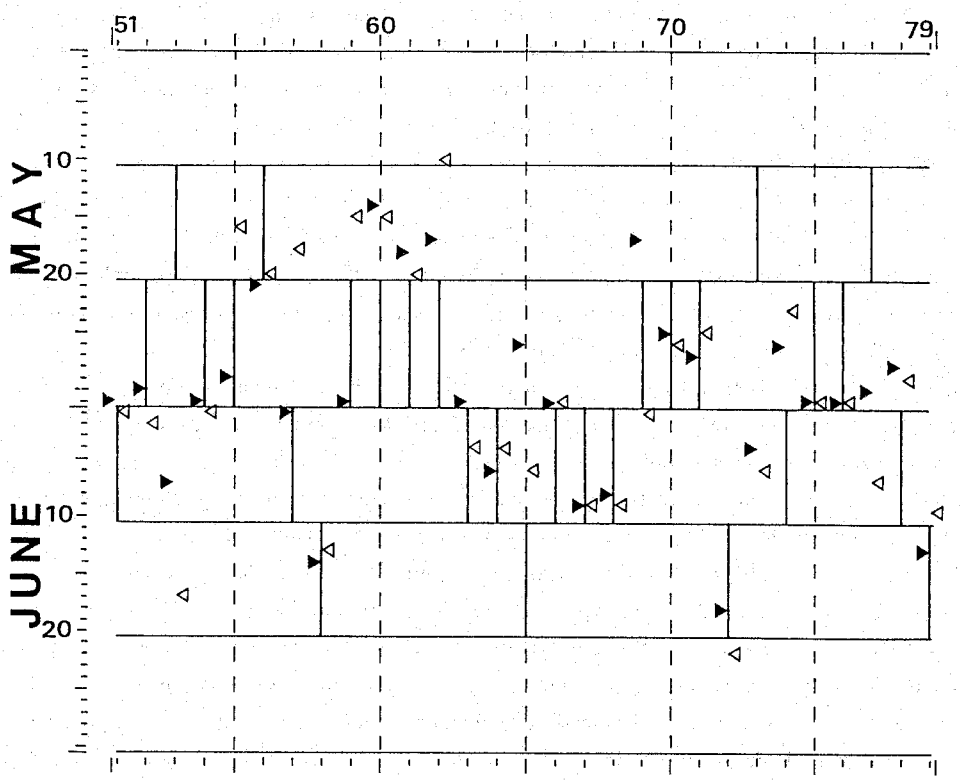
The onset date is different among the three regions, i.e. the region between 10°N and 17°N, between 17°N and 19°N and the north of 19°N; 3 years out of 29 years from 1951 to 1979, 1 year out of 20 years from 1960 to 1979

The number of years that the onset are regionally different, OT2-OT4, is 14 out of 20 years from 1960 to 1979. The most frequent onset pattern in the Indochina summer monsoon is OT3 as classified above. The onset south of 19°N occurs in mid-May and that north of 19°N in early June.

Most of the onsets occur in May in the Indochina Peninsula. During May, a tropical cyclone also develops in the Bay of Bengal and it is connected with the northward shift of ITCZ. In the region south of 19°N, the number of years that the tropical cyclone connected with the onset is 10 years (50%) based on an analysis of 20 years from 1960 to 1979 (Table 1). Orgill (1967) showed that two thirds of the onsets were connected with tropical cyclones based on his analysis of the 29 years from 1936 to 1964. Although the onsets connected with the cyclone decrease during the 20

years from 1960 to 1979 of this study in comparison with Orgill's study period, the tropical cyclone or depression that originated in the Bay of Bengal is an important factor for the onset of the Indochina summer monsoon.

The relationship between the onset along the west coast of the Indochina Peninsula and Kerala, the southern tip of India, is analyzed in order to determine the relationship between the Indochina summer monsoon and the Indian summer monsoon using the onset dates for the 29 years from 1951 to 1979 as data. The onset north of 25°N in the Indochina Peninsula, the northernmost region (NI), corresponds closely with that in Kerala (Table 1 and Fig. 2). In particular, the onset date for Kerala, according to India Meteorological Department records (IMD), corresponds closely with that



| : Onset 10-day period of northernmost part of Myanmar

◁ : Onset date in the northern part of Kerala (after Ananthakrishnan and Soman; 1988)

▶ : Onset date in Kerala, defined by IMD (India Meteorological Department) records (after Ananthakrishnan and Soman; 1988)

Figure 2. Relationship of the onsets between the Indochina Peninsula and the southern part of India (Kerala).
The onset dates are also shown in Table 1.

of NI. From the onset date of IMD in Kerala, the mean onset date is the end of May with a range from mid-May to mid-June. The mean onset date and its range in Kerala correspond well north of 25°N in the Indochina Peninsula. The number of years in which the onset of IMD occurs during the onset of NI is 15, representing more than half of the study period. When the onset of NI is earlier than that of IMD, the onset of NI occurs in mid-May. On the other hand, when the onset of NI is later than that of IMD, most of the onsets in NI occur one 10-day period after that of IMD. The second onset of OT3, the most frequent onset pattern in the Indochina summer monsoon as classified above, is in accordance with the onset in Kerala.

IV. Regional characteristics of precipitation around the onset

The regional characteristics of precipitation distribution before, at and after the onset are analyzed based on the mean precipitation maps of three types of onsets, OT1, OT2 and OT3 as clarified above. The 10-day mean precipitation maps for each type of onset are made based on the following criteria. The mean 10-day precipitation data before the onset are those of two 10-day periods just before the onset, and the mean 10-day precipitation data after the onset represents two 10-day periods just after the onset. When the onset occurs in two stages, OT2 and OT3, the mean 10-day precipitation data at the first onset are from the first onset to the 10-day period just before the second onset. The onset of OT1 and the second onsets of OT2 and OT3 are analyzed only using the 10-day precipitation data at the onset. Secondly, the mean 10-day precipitation data for each year are averaged in each climatic type. Three mean maps are prepared in the case of OT1 and four mean maps are prepared for OT2 and OT3.

During the pre-monsoon season, the regional differences in precipitation are not so obvious in the three types of onsets, OT1-OT3 (Figs. 3-a, 4-a, 5-a). Heavy rains occur around 10°N along the west coast. While, the 10-day precipitation in the central and northern parts of Myanmar is less than that in Thailand. The distribution of pre-monsoon precipitation does not show a large regional diversity compared with the 10-day precipitation distribution at and after the onset.

When the onset is different between north and south of 17°N, in the case of OT2, the mean 10-day precipitation during the first onset is more than 100mm south of 17°N and more than 50mm between 17°N and 19°N along the west coast (Fig. 4-b). The precipitation in the northern mountainous areas is more than 50mm south of 23°N and is more abundant than that at the same latitudes along the west coast. In Thailand, precipitation is more abundant than that of the second onset, and regional diversity of precipitation is slight. In this case, ITCZ is located in the central part of Thailand for a longer period than the other types of onset. Therefore, it is considered that precipitation is abundant in Thailand and the regional diversity of precipitation is small compared with that at and after the second onset.

When the onset is different between north and south of 19°N, in the case of OT3, the mean precipitation at the first onset is more than 100mm as far as 19°N along the west coast (Fig. 5-b). The precipitation in the northern mountainous region is more than 50mm south of 25°N and the isohyets of 50mm as further north than OT2. In Thailand, the regional diversity of precipitation is also small compared with at and after the second onset.

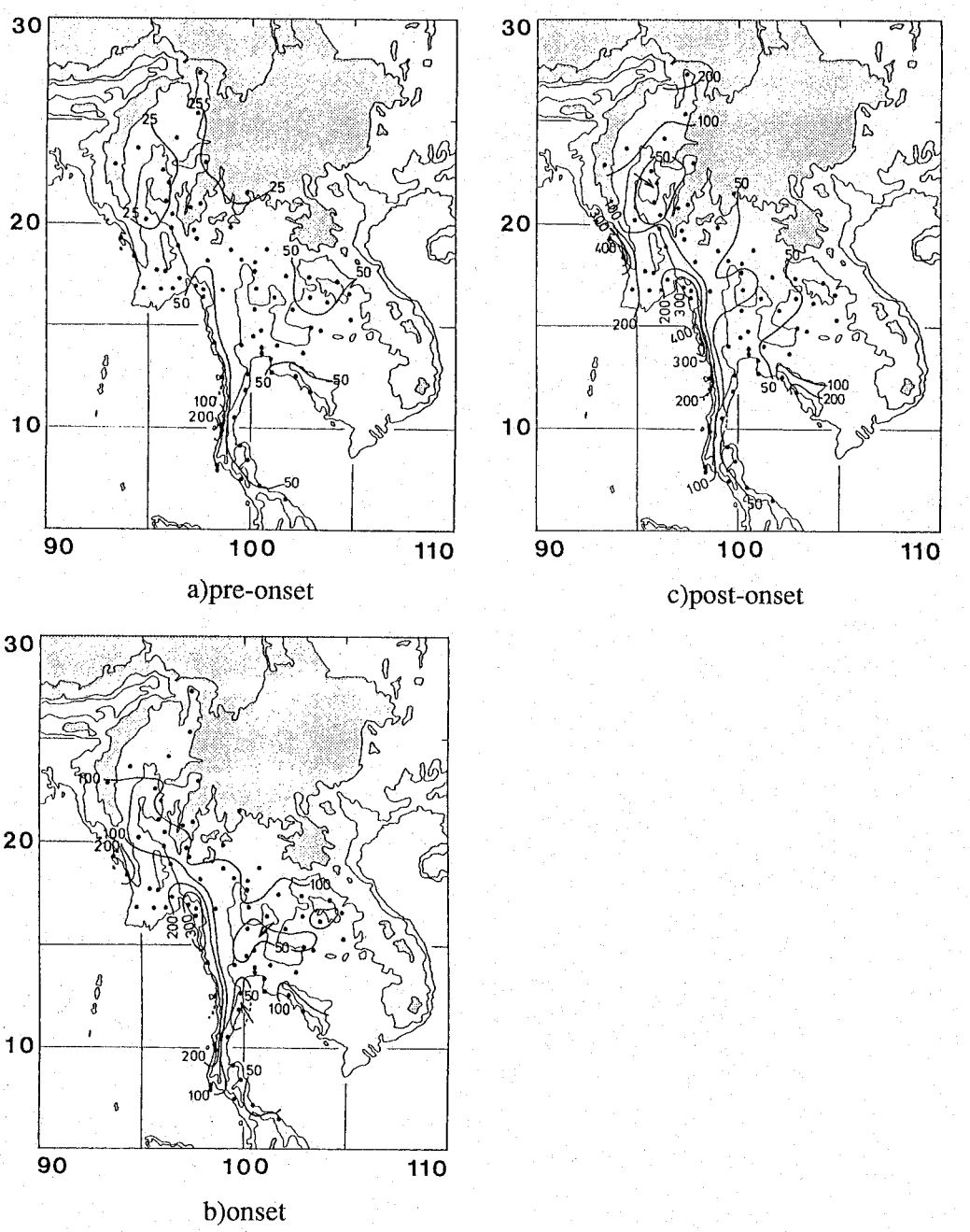


Figure 3. 10-day mean precipitation maps before, at and after the onset of Indochina summer monsoon in case that the monsoon begins at the same time in whole regions. Units; mm.
a) pre-onset, b) onset, c) post-onset

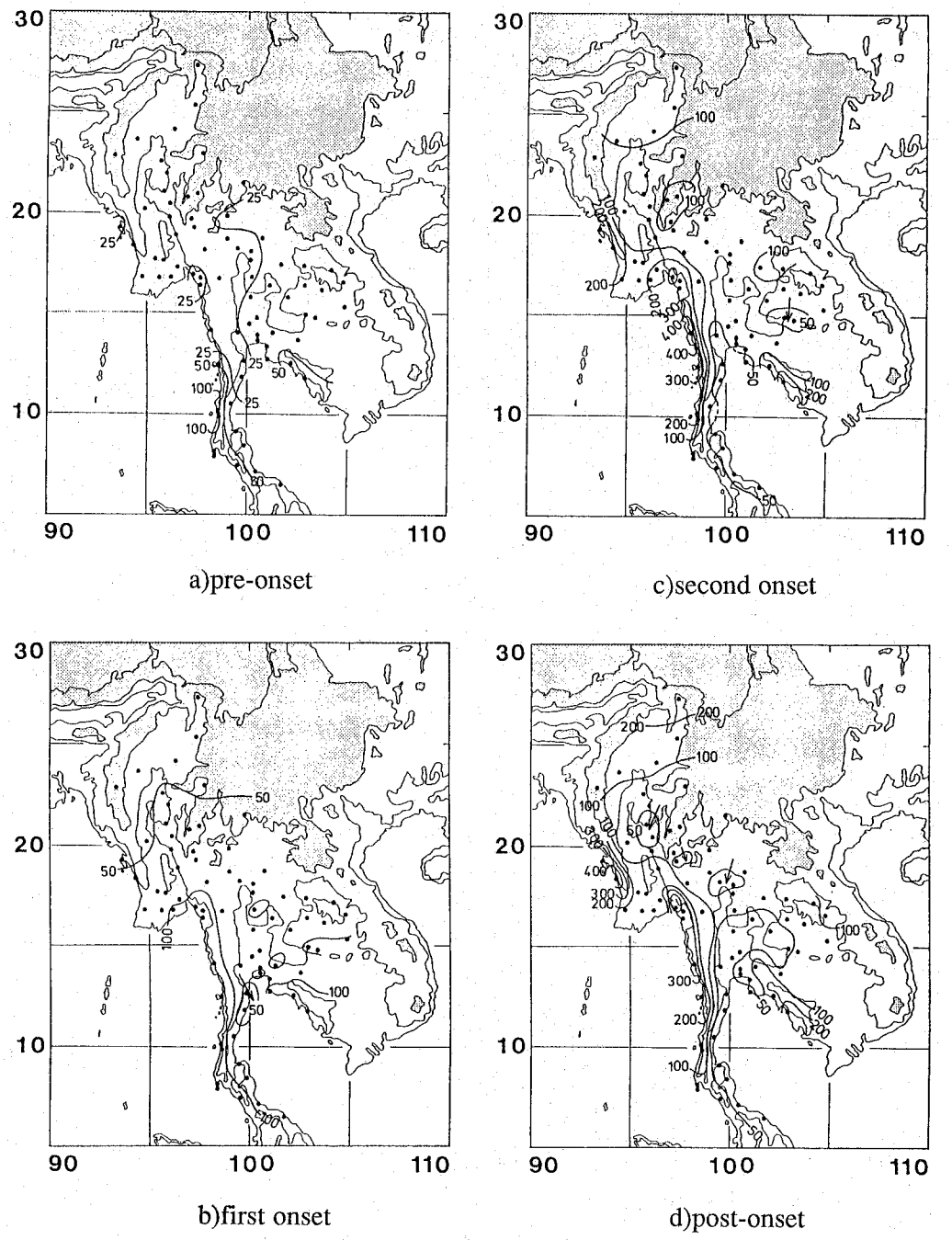


Figure 4. 10-day mean precipitation maps before, at and after the onset of Indochina summer monsoon in case that the onset occurs at two steps and it's boundary is located around 17°N. Units; mm.
a) pre-onset, b) first onset, c) second onset, d) post-onset

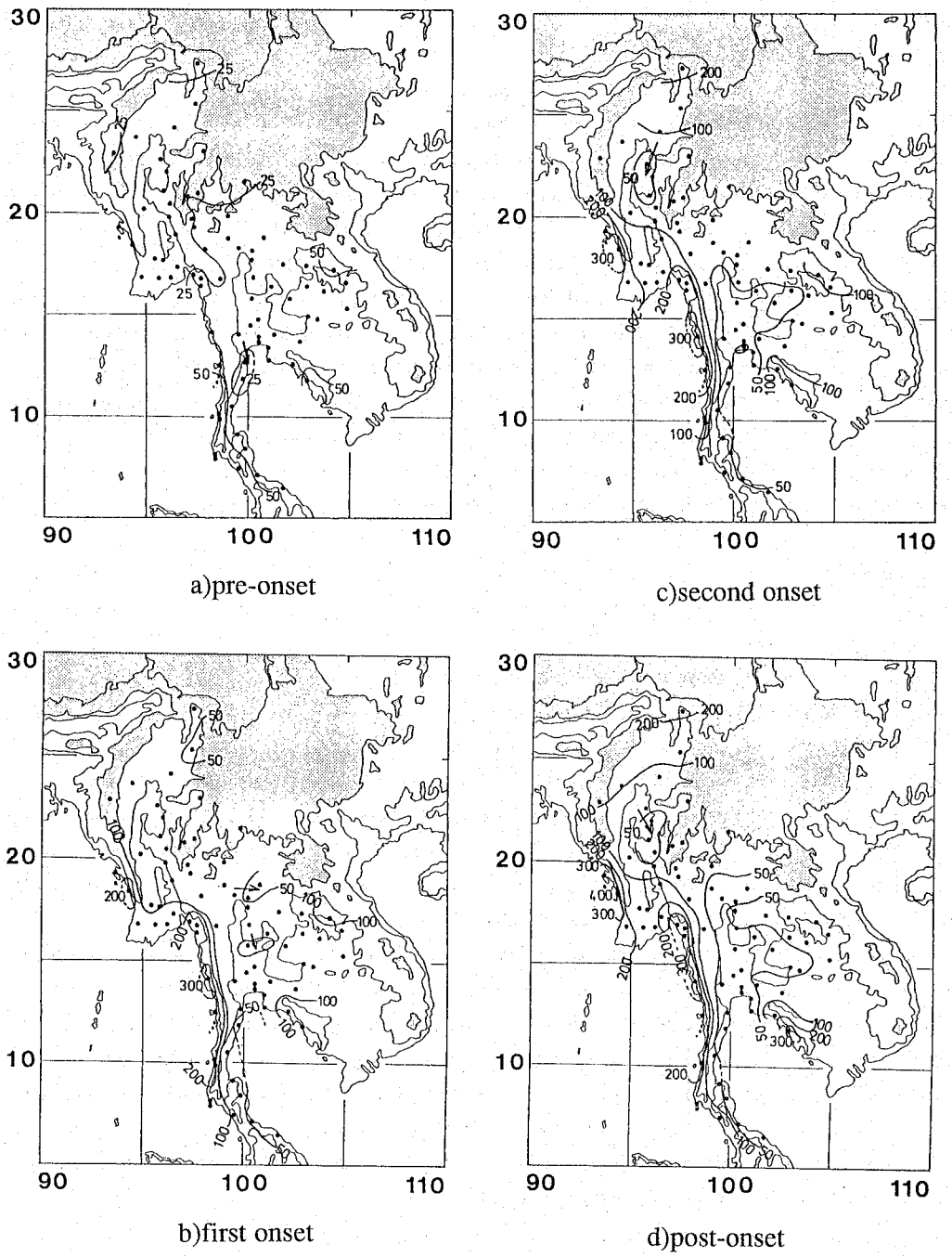


Figure 5. 10-day mean precipitation maps before, at and after the onset of Indochina summer monsoon in case that the onset occurs at two steps and it's boundary is located around 19°N. Units; mm.
a) pre-onset, b) first onset, c) second onset, d) post-onset

When the onset occurs in the whole Indochina Peninsula, in case of the onset of OT1 and the second onsets of OT2 and OT3, precipitation increases in the northernmost part of Myanmar (Figs. 3-b, 4-c, 5-c). The precipitation distribution is almost the same as that after the onset. However, after the onset, precipitation decreases in the basins of northern Myanmar and the Central Plain of Thailand, and the regional difference in precipitation is obvious (Figs. 3-c, 4-d, 5-d). During this period, ITCZ shifts north of the Indochina Peninsula and the southwesterlies prevail over the Indochina Peninsula. Precipitation is abundant in the windward regions against the southwesterlies but decreases in the leeward basins and plains against the southwesterlies.

These changes in precipitation distribution before, at and after the onset are considered to be related to the changes in synoptic conditions. At the onset period, precipitation is mainly brought by ITCZ and tropical cyclones. The precipitation brought by ITCZ shows an abundant precipitation zone along ITCZ and the regional difference in precipitation is relatively small. However, after the onset, the southwesterlies prevail over the Indochina Peninsula and the precipitation is mainly brought by disturbances in the southwesterlies and the monsoon troughs. The precipitation brought by the southwesterlies is restricted in the windward regions of mountains and the difference in precipitation between the windward and leeward regions of mountains becomes large.

V. Conclusions

The regional characteristics of the summer monsoon onset are analyzed in the western part of the Indochina Peninsula.

Based on data covering a period of 29 years from 1951 to 1979, the onset of the Indochina summer monsoon differs regionally along the west coast and their boundaries are located around 17°N and 19°N. The mean onset date is mid-May south of 17°N, the first half of late May between 17°N and 19°N and the latter half of late May north of 19°N. The onset connected with the tropical cyclone represents 50% of all onsets south of 19°N and tropical cyclone originating in the Bay of Bengal is an important factor on the onset of the Indochina summer monsoon. The onset date north of 19°N along the west coast and that of the northernmost region of Myanmar correspond closely with those of Kerala, the souther tip of India.

The precipitation distribution changes before, at and after the onset. Before the onset of the Indochina Peninsula, precipitation is more abundant in Thailand than along the west coast (Fig. 6-a). During the period from the first onset of the Indochina summer monsoon to the onset of the summer monsoon in the whole Indochina Peninsula, heavy rains occur around ITCZ and the regional differences in precipitation are relatively small (Fig. 6-b). After the onset of the summer monsoon in the whole Indochina Peninsula, precipitation increases in the windward regions against the southwesterlies but decreases in the leeward basins or plains against the southwesterlies. The regional difference in precipitation increases (Fig. 6-c).

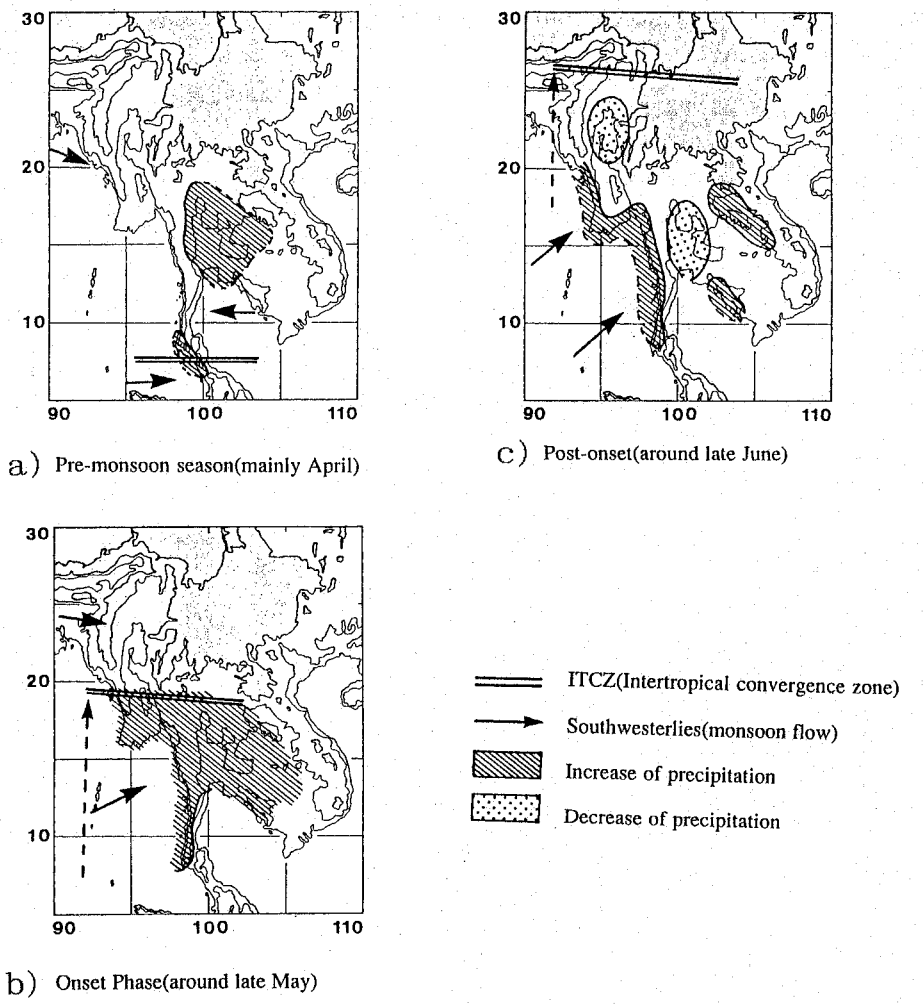


Figure 6. Schematic map of regional differences in precipitation around the onset of the Indochina summer monsoon.

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