

RAINY SEASONS IN THE NANSEI-SHOTOU (SOUTHWEST ISLANDS) OF JAPAN

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Abstract The seasonal changes of precipitation in the Nansei-Shotou (Southwest Islands) of Japan are investigated using 20-year (1979-98) averaged pentad rainfall data. Four major climatological rainy seasons are recognized over this region. 1) The spring rainy season from mid-March to early May, more obvious in the northern part, caused by extratropical cyclone and frontal systems. 2) The early summer rainy season from mid-May to mid-June corresponding to *Bai-u*, of which onset, peak and end migrate northward. 3) The late summer rainy season from late July to late August, more obvious in the southern part, caused mainly by typhoons passing over this region westward or northward. 4) The autumnal rainy season from mid-September to late September, influenced by typhoons but those migrating northeastward recurring around this region. The influence of Japanese *Akisame* (Autumnal rain) frontal zone is recognized only in the northern part.

Key words: rainy season, seasonal changes, *Bai-u*, *Aki-same* (Autumnal rain), typhoon

1. Introduction

The Southwest Islands, called *Nansei-Shotou* in Japanese, stretch southwestward approximately 800km from the south of Kyushu, the southern most main island of Japan, to the east of Taiwan (Fig. 1). They are divided into two major islands, the Satsunan Islands in the north and the Ryukyu Islands in the south bounded at around 27° N between Yoron-tou and Okinawa Island. Since the Ryukyu Islands were occupied by the United States after 1945 until 1972, little descriptions were devoted in the English climatology of Japan. For example, Arakawa and Taga (1969) listed monthly climatic tables at two stations (Naze and Naha) in the Southwest Islands but they made no specific descriptions. Fukui (1977) briefly mentioned the climatic features of these Islands. In Japanese literatures, on the other hand, more minute climatic descriptions have been made, for example, Uchijima (1985), Yamazaki *et al.* (1989), Nakamura *et al.* (1996). Ishijima (1975) described the seasonal characteristics of precipitation in Okinawa Islands. The peculiarities of the climate in the Southwest Islands compared with those in the Japanese main Islands in these previous literatures are summarized as: earlier rainy season called *Bai-u* in Japanese, longer hot summer season, more frequent typhoon visit. Chen *et al.* (1999) presented four seasonal rainfall variation patterns by utilizing dense monthly mean precipitation data in Taiwan. Chen *et al.* (2004)

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further documented that early summer and autumnal rainfall is mainly attributed to *Bai-u/Mei-yu* frontal activity, while mid-summer rainfall is mainly caused by tropical cyclones including typhoons in Taiwan. However, detailed seasonal rainfall patterns in the whole Southwest Islands have not been analyzed yet, and their regional differences have not been documented. In the present study, the authors investigate the regional features of climatological rainy seasons in the whole Southwest Islands of Japan.

2. Data and Method

The data utilized are daily precipitation based on AMeDAS (Automated Meteorological Data Acquisition System) of JMA (Japan Meteorological Agency). There are 35 stations in this island region. Also utilized are the data of Kagoshima located in the southern part of Kyushu. The location of stations is shown in Fig. 1. The analyzed period is twenty years from 1979 to 1998. Pentad mean precipitation data are constructed from daily mean values for this 20-year period. In order to investigate the synoptic situations related to precipitation, location of fronts and typhoon tracks in each pentad are mapped using daily surface weather charts published by JMA.

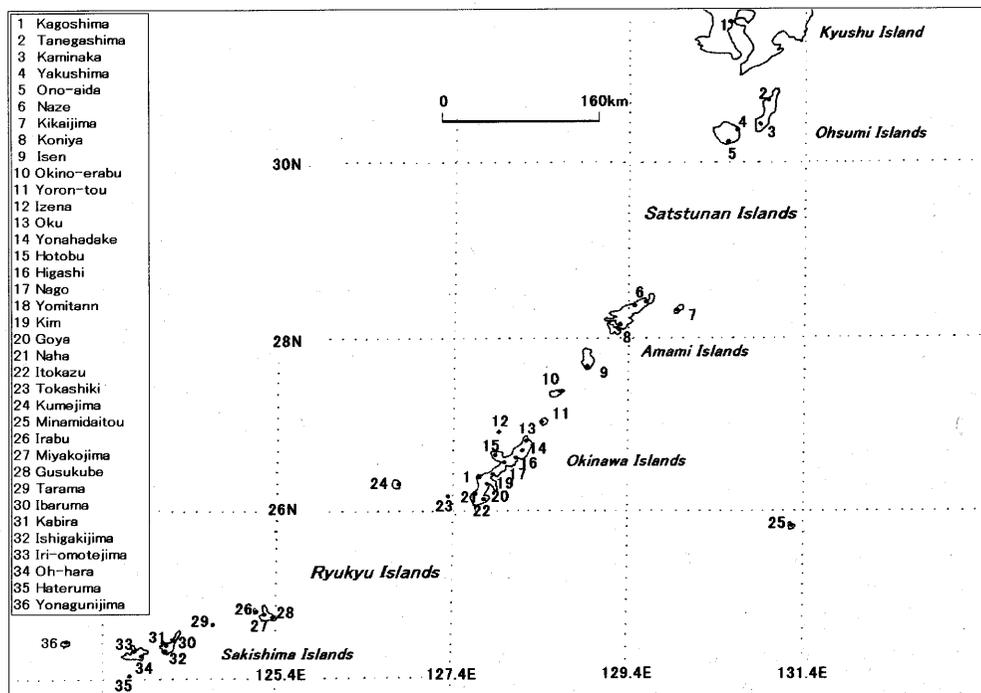


Fig. 1 Location of stations.

3. Rainy Seasons

In order to define the climatological rainy period, the pentad mean annual precipitation (PMAP) is calculated by the following equation (1), as did in Matsumoto (1997).

$$\text{PMAP} = \text{Mean annual precipitation} / 73 \text{ (Number of pentad in a year)} \quad (1)$$

The rainy pentad is then defined as the pentad in which pentad mean precipitation exceeds PMAP. The annual variations of pentad mean precipitation at Yoron-tou (No. 11 in Fig. 1) is presented in Fig. 2. In Fig. 2, there are some periods when rainy pentads continue for several pentads. Here, the rainy season is defined as the period when the rainy pentads continue in at least four consecutive pentads as shown by arrows in Fig. 2. The rainy pentads and rainy seasons at all the analyzed stations are shown in Fig. 3, in which stations are roughly aligned from north to south, in order to see the meridional differences. According to Fig. 3, four main rainy seasons can be pointed out for major part of the Islands, spring (from Pentad 15 to Pentad 26), early summer (from Pentad 28 to Pentad 35), late summer (from Pentad 45 to Pentad 48), and autumn (from Pentad 53 to Pentad 56). The periods in the parentheses are for Yoron-tou where all these rainy seasons are recognized and they are somewhat different with regions. The regional characteristics of these rainy seasons are as follows.

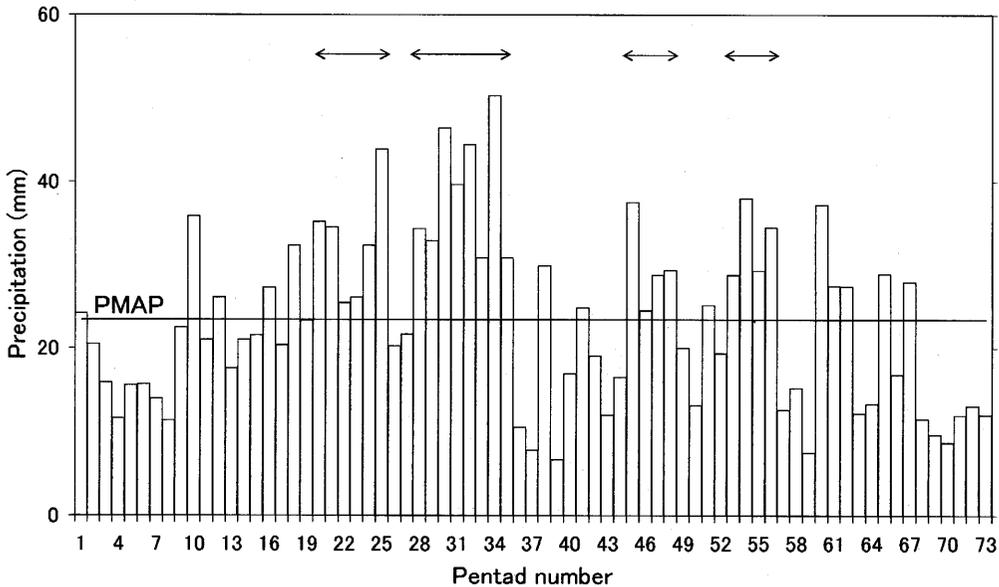


Fig. 2 Time-series of 5-day mean precipitation at Yoron-tou. Horizontal line indicates the pentad mean annual precipitation (PMAP). Arrows indicate the rainy seasons.

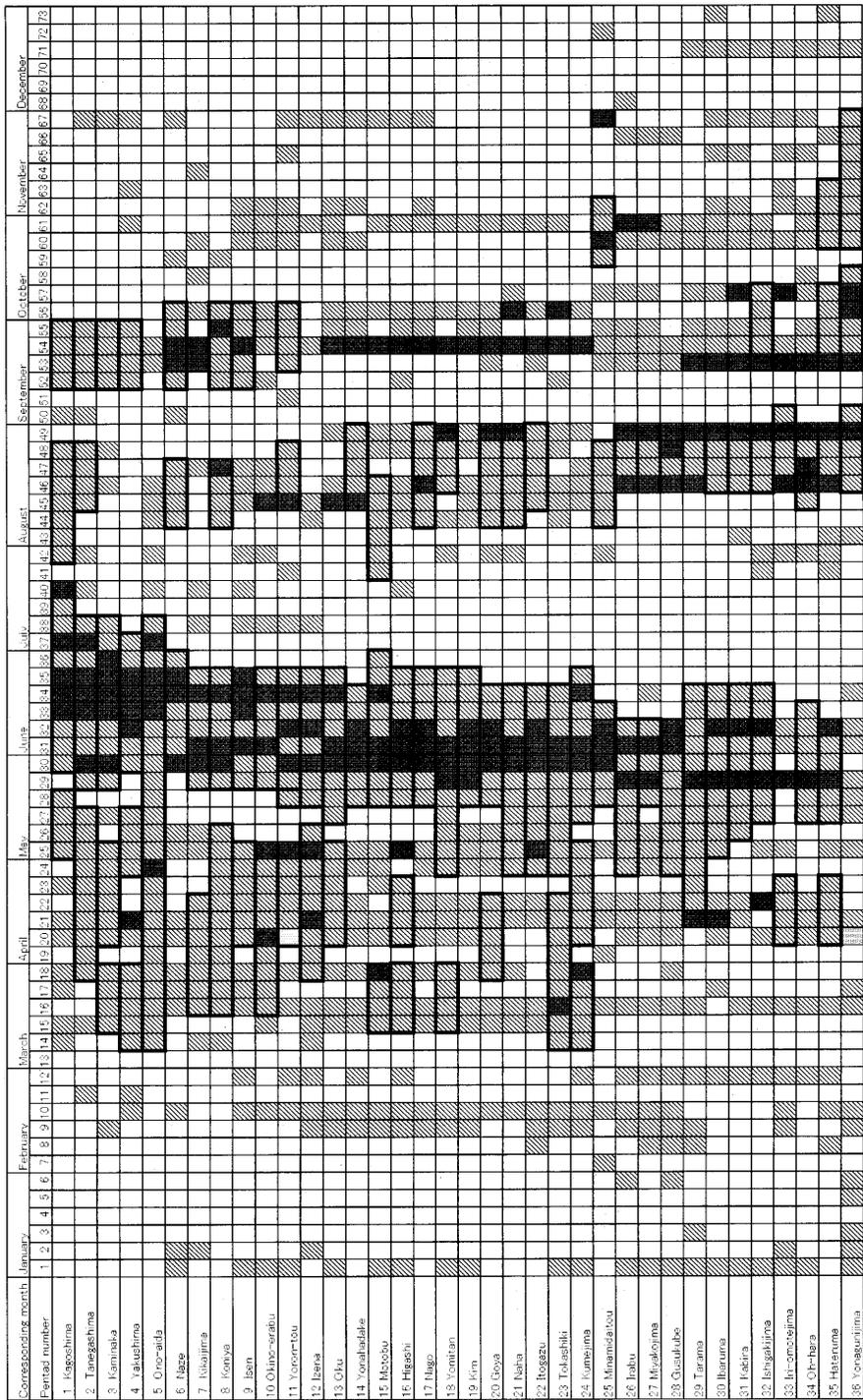


Fig. 3 Rainy pentads and rainy seasons in the Southwest Islands.

Spring rainy season

This rainy season is not clear at all stations. In general, it is more outstanding in the northern part, but not recognized at Kagoshima. The commencement of this rainy season is earlier in the north and west of Okinawa and corresponds to early March (Pentad 14). That in the southern part in the Sakishima Islands is, although not well defined at some stations, in early April around Pentad 20. The zone of maximum rainfall is generally located in the central part around the Amami Islands. The main cause of rainfall in this period is extra-tropical cyclones and associated frontal systems. The end of this period is not very clear at some stations, but it is roughly speaking around early May (Pentad 25-26). The period of this rainy season is corresponding to the persistent spring rain in central China (Tian and Yasunari 1998), which is called *Lian-yin-yu* in Chinese.

Early summer rainy season (*Bai-u*)

The rainfall characteristics change drastically in early to mid-May (Pentad 26-28). After Pentad 26, the zone of maximum rainfall migrates first from the central part around the Amami and Okinawa Islands to the southern part in the Sakishima Islands in early to mid-May. Then it gradually migrates northward. The beginning of this season well corresponds to the large-scale abrupt seasonal changes of rainfall characteristics by Hirasawa *et al.* (1995), to the seasonal divisions by Matsumoto (1992), characterizing the onset of the first stage of *Bai-u* season in East Asian monsoon region. The rainfall amount apparently increases from mid-May at almost all stations. The main cause of rainfall in this period is the stagnating fronts called *Bai-u* front. The northward migration of the zone of maximum rainfall shown in Fig. 4 is clearly recognized corresponding to the northward shift of the *Bai-u* frontal zone. The peak of rainfall occurs in late May (Pentad 29) in the Sakishima Islands, in late May (Pentad 30) in the Okinawa Islands, while, it is after mid-June (Pentad 34) in the north of Okinawa. The end of *Bai-u* is also earlier in the southern part. It is in late June (Pentad 34) in the Sakishima Islands, in late June (Pentad 35) in the Okinawa and the Amami Islands, and in early July (Pentad 38) in the Ohsumi Islands. After the end of this rainy season, rainfall amount clearly decreases in the whole region characterizing mid-summer dry spell. Severe droughts often occur in this hot and dry season.

Late summer rainy season

After late July (Pentad 42), rainfall amount begins to increase again. This is corresponding to the end of *Bai-u* season in the main Islands of Japan (Maejima 1967; Matsumoto 1992), and abrupt shift of strong convective region in the western North Pacific (Ueda *et al.* 1995). Late summer rainy season begins in early August (Pentad 44) in the northern and central part except some stations, while it starts in mid-August (Pentad 46) at all the stations in the Sakishima Islands. In some cases, mean 5-day rainfall amount exceeds 80 mm, thus indicating strong rainfall intensity in this season. The main cause of rainfall in this period is typhoons. The maximum zone of rainfall lies in the Sakishima Islands.

Autumn rainy season

In early September (Pentad 50 and 51) the rainfall amount clearly decreases in most stations. This is just corresponding to the beginning of Autumnal rainy season (*Shurin* or *Akisame* in Japanese) in the Japanese main Islands (Maejima 1967; Matsumoto 1988, 1992). After that, from mid-September to early October, rainy season is recognized in most of the Ohsumi and Amami Islands. In the central part, including the Okinawa Islands, this rainy season is not very clear, although higher rainfall amount is observed in a specific pentad (Pentad 54) in late September. The main cause of rainfall in this region is stationary fronts associated

with *Akisame* (Autumnal rain) front. On the other hand, rainy season is also recognized almost at the same time in the Sakishima Islands in the south. The cause of this rainy season is due to frequent typhoon visit.

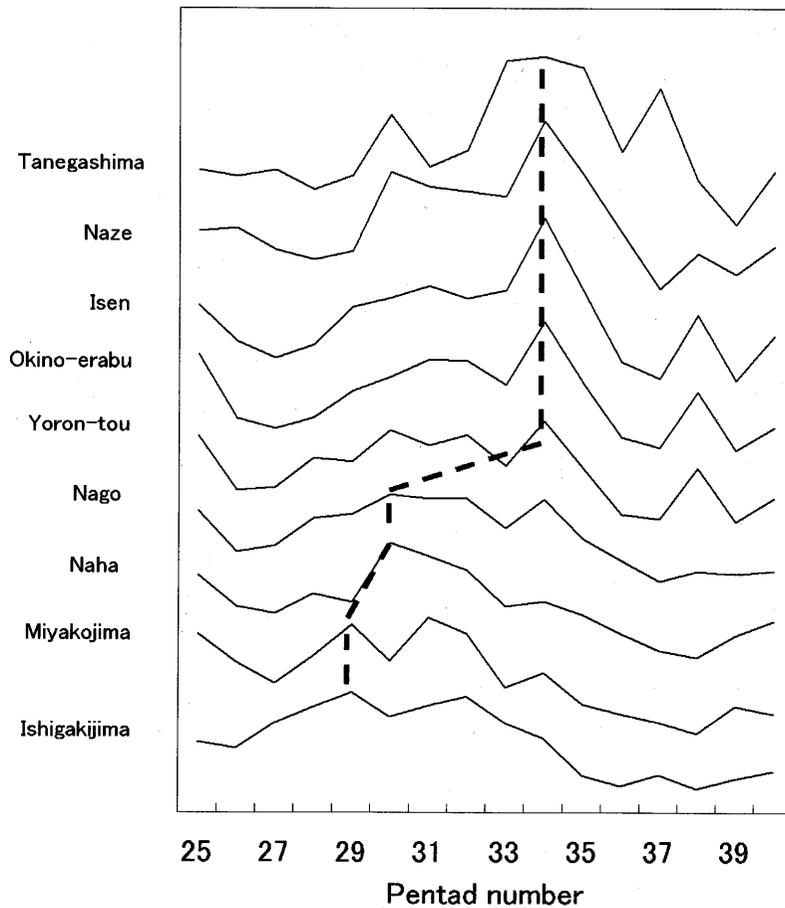


Fig. 4 Pentad mean precipitation around *Bai-u* season over the Southwest Island. Stations are aligned downward from north to south. Thick dotted line indicates the seasonal northward shift of the maximum precipitation period.

4. Conclusions

Four major rainy seasons are recognized in the Nansei-Shotou (Southwest Islands) of Japan. The spring rainy season begins in mid-March caused by the extra-tropical cyclone and frontal systems in the south of Japan. This season is more obvious in the northern part, but it is not very prominent in the main Islands of Japan (Maejima, 1967). The early summer rainy season corresponding to Japanese *Bai-u* begins

in mid-May, about one month earlier than that in the Japanese main Islands. The onset, peak and end of this rainy season migrate northward as the *Bai-u* frontal zone shifts northward. This season is recognized in almost all the Southwest Islands. The late summer rainy season, which is not apparent in the main islands of Japan, is caused mainly by typhoons passing over the Southwest Islands region migrating westward or northward. This season is more obvious in the southern part. In autumnal rainy season, the Southwest Islands are influenced by typhoons which migrate northeastward recurving around these islands. Only in the northern part, the influence of *Akisame* frontal zone is pronounced.

Maejima (1967) recognized both *Bai-u* and *Akisame* seasons in all part of Japan except Hokkaido, the northernmost main island. But the Southwest Islands were not included in his study. In the present study, it has been revealed that although *Bai-u* season is recognized in the almost whole analyzed region, *Akisame* season caused by frontal activity is recognized only in the north of Yoron Island. In other words, there is a southern limit for the activity of the *Akisame* frontal zone, which is located between Okinawa and Yoron Island. The seasonal changes of rainy season are also different from those in Taiwan pointed out by Chen *et al.* (1999, 2004). As such, the rainfall season in the Southern Islands shows unique characteristics in the East Asian monsoon, influenced by extra-tropical cyclones, *Bai-u* and *Akisame* frontal zones and tropical disturbances including typhoons.

Since the influence of typhoons on the rainy season is more important here than that in the main islands of Japan, the year-to-year variability will be larger in the former region. Further studies are needed for the interannual variability of these rainy seasons.

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(*: in Japanese)