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ANALYSIS OF THE CHARACTERISTICS OF SUSTAINED TORRENTIAL RAINS IN JUNES DURING 1958-2000

DING Zhi-ying (丁治英)[1, 2], CHANG Yue (常　越)[1, 2, 3], ZHU Li (朱莉)[1, 2], HE Jin-hai (何金海)[1, 2]

(1. Jiangsu Key Laboratory of Meteorological Disaster, NUIST, Nanjing 210044 China; 2. Department of Atmospheric Sciences, NUIST, Nanjing 210044 China; 3. Weather Bureau of Guangzhou, 510080 China)

Abstract: Day-to-day precipitation data of Junes during the 43 years of 1958-2000 from stations to the south of Yangtze River are used to divide regions and run statistical analysis of sustained torrential rainfall processes. A preliminary analysis is then made based on it and the results show that June is the month in which torrential rains in the southern half of China take place frequently and sustained torrential rains occur at the same time in South China and the area to the south of Yangtze River. In addition, the analysis gives the basic features of sustained torrential rains of June in China and their interannual variability patterns, with the suggestion that the amount of these events increases significantly after the 1990s. Lastly, the sustained torrential rains occurring in Junes of 1994, 1998 and 2005 in the southern half of China are taken as examples in the research on the basic patterns and formation mechanisms of the evolution of double rain-bands during the rain season in South China and the area to the south of Yangtze River. The analysis shows that the large scale environment field in which sustained torrential rains occur is related to the stable sustaining of the South Asia High and upper level jet streams.

Key words: sustained torrential rains; South Asia High, upper level jets; South China; dual rain bands

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1 INTRODUCTION

Characterized by high intensity, long duration, substantial seasonal change, extensive areas of exposure and large regional differences, torrential rains in China may last for a few minutes or a few dozens of days. Generally speaking, they usually have a life cycle of 1 – 7 days and more than 10 days at maximum with the Mei-yu (sustained) raining season in the Yangtze and Huaihe River attachments. Annually, principal rain bands are closely linked with the advancement and retreat of the summer monsoon and the location of the ridge of the western Pacific subtropical high. Three main raining seasons are resulted during the northward progression of summer monsoon, respectively in South China, the Yangtze and Huaihe River attachments and Northeast China. June is the month in which sustained torrential rains occur the most [1] and over both South China and the area just south of the middle and lower sections of the Yangtze River, exposing people's livelihood and property to tremendous threat. It is then necessary to study these sustained torrential rains for the causes and characteristics.

Torrential rains, whether they are sustained or not, have drawn much attention from the meteorological community. Their occurrence in China is governed by three large-scale factors: the summer monsoon from the Indian Ocean and western Pacific, the subtropical high over the western Pacific and Tibet-Qinghai Plateau, and anomalous atmospheric circulation over the Northern Hemisphere, especially the middle and higher latitudes in East Asia (Ding et al.)[2]. The sustained torrential rains in the Mei-yu season over the middle and lower reaches of the Yangtze in 1998 and 1999 were the result of specific large-scale circulation background (the subtropical high, a "dam" of high pressure in North China and low vortexes south of the plateau) [3, 4]. A torrential rain in June 1999 was

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Biography: DING Zhi-ying, female, native from Jiangsu province, professor, undertaking the research on mesoscale dynamics and numerical simulation.
E-mail for correspondence author: lvran0122@163.com

resulted from interactions between mid- and lower-level systems (low-level shears, low vortexes and southwesterly jet streams) in specific weather background [5]. The anomalies of atmospheric circulation are one of the immediate causes for those of precipitation [6]. As shown in an analysis of a sustained torrential rain from 23 to 28 June, 1999 [7], instable energy, which is important for the sustaining of rain, is rebuilt when the energy upstream of a rain zone is transported to it via advection.

What is presented above is, however, only some of the case studies addressing single or sustained torrential rains within short periods of time [8, 9] while there have not been much work on statistical study of the characteristics of torrential rains and sustained torrential rains for the past few dozens of years. Furthermore, the study of sustained torrential rains mainly focuses on the effect of low-level systems while few attempts have been made to study the impacts of upper-level jet streams and South Asia High on sustained torrential rain. The divergence field from which torrential rains are generated should be directly linked with them. These two types of rains are not weather phenomena taking place at an isolated site or within a short period of time, they are instead highly correlated with such mean climatological features as the general circulation and climatic anomalies. It is then seen that it is realistically important to study, obtain and compile the statistics of torrential rains over the past few dozens of years in China.

2 CHARACTERISTICS OF TORRENTIAL RAINS AND SUSTAINED TORRENTIAL RAINS IN JUNE SOUTH OF YANGTZE

2.1 *Data, classified regions and standards for sustained torrential rains*

Fig.1a gives the distribution of the frequency of torrential rains measured at 284 stations in the area south of 34°N during the 43 years of 1958 – 2000. It shows that torrential rains mainly occur in areas south of the Yangtze River and west of 103°E. With the definition of torrential rains for single stations by Tao [10], which classifies rainfall of more than 50 mm every day lasting for three days running at a single station as sustained torrential rain [11], the distribution of torrential rains for 730 single stations in June across China is determined with the day-to-day precipitation data from 1951 to 2005. See Fig.1b. The results are similar to those in Fig.1a. It is known from a comparison of them that a basin in central China where there are two lakes, i.e. Dong Ting Lake and Bo Yang Lake, is the region within the country where torrential rains happen frequently and sustained torrential rains

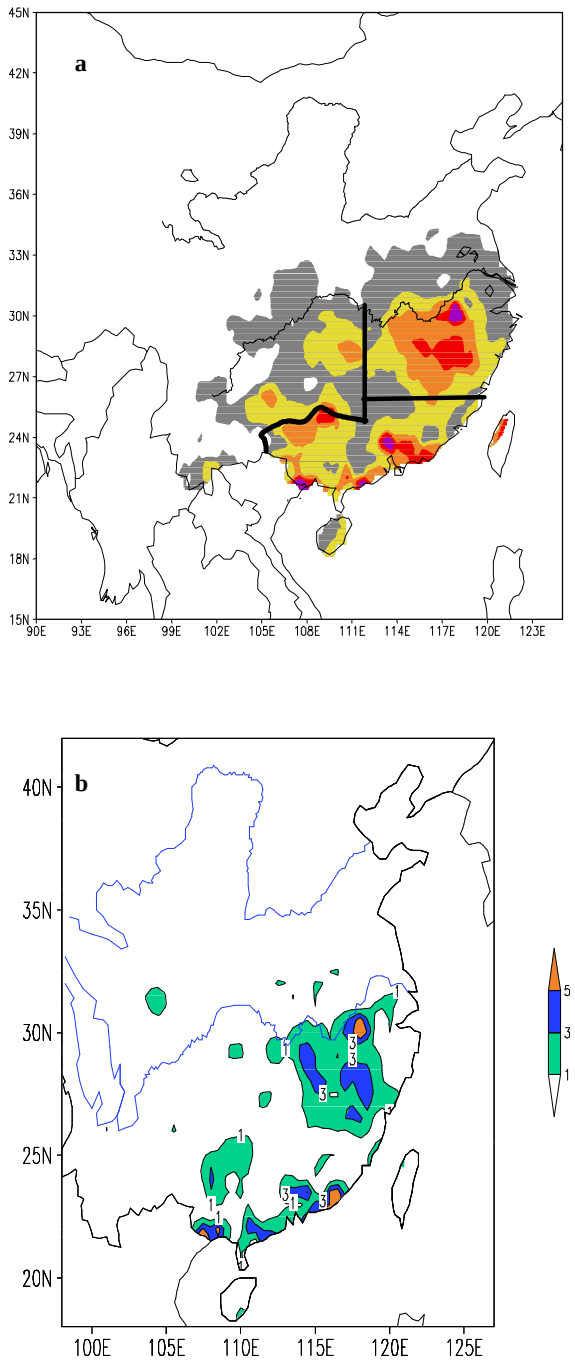

Fig.1 (a) The distribution of the frequency of torrential rains measured at various stations in Junes of 1958 – 2000, with the interval at 20 and the central shade >80. (b) Same as (a) but for single stations [10].

are the most intense. Torrential rains occur relatively frequently in the upper reach of the Yangtze River while sustained torrential rains appear rarely. The same is true in South China and the western part of Nanling Mts. Other areas with good correspondence between torrential rains and sustained torrential rains are Fujian, Guangdong and Guangxi. The analysis above shows

that torrential rains and sustained torrential rains in June mainly concentrate in three areas south of the Yangtze River: the two-lake basin, parts of Fujian, Guangdong and Guangxi south of the Nanling Mts. and a plateau over Yunnan, Guizhou and Sichuan provinces (YGS Plateau). This study focuses on the characteristics of sustained torrential rains south of the Yangtze River.

The day-to-day precipitation data from 152 observation stations south of the Yangtze River and the definition of torrential rains are used to study the characteristics of interdecadal temporal and spatial variation of the sustained torrential rains over the 43 years in China. For the convenience of analysis, the region is divided into three portions, namely, Reg.I (south of Yangtze River, north of 26°N and east of 112°E, comprising 61 stations), Reg.II (south of 26°N and east of 105°E, consisting of 45 stations in Guangdong, Guangxi and Fujian), and Reg.III (south of Yangtze River in the YGS Plateau from 112°E to 103°E, including 46 stations). In the meantime, the islands of Taiwan and Hainan are not included for lack of data from the former and the large difference in the frequency of precipitation between the latter and the northern part of the continent. Regions I, II and III have distinctive geographic distribution features of their own. Reg.II has relatively low elevation above sea level that increases gradually to the north and reaches the highest point near 25°N. Reg. I is also mountainous with the two-lake basin in sharp contrast with flat topography to the north. Reg.III is mostly made up of low-latitude plateau with complicated topographic landform.

Following the general definition that a day with diurnal rainfall ⩾ 50 mm for at least one station in one of the regions above is said to have torrential rains, sustained torrential rains are defined to occur in one of the following regions if, together with consideration of the factors of rainfall and rain duration as well as the region over which the rain falls, for Reg.I, at least one station has the rainfall ⩾ 50 mm and torrential rains occur at ⩾15 stations or times for three days in a row; for Reg.II, at least one station has the rainfall ⩾ 50 mm and torrential rains occur at 18 stations or times for three days in a row; for Reg.III, at least one station has the rainfall ⩾ 50 mm and torrential rains occur at 10 stations or times for three days in a row.

2.2 *General characteristics of sustained torrential rains in the three regions in Junes of 1958 – 2005*

It is known from Table 1 that Reg.I has the most sustained torrential rain for the period, followed by Reg.II and Reg.III has the least. Reg.I and Reg.II are comparable in their contribution to this type of rains while Reg.III has the weakest intensity of rain among them.

It is also known from Table 2 that the YGS Plateau has the least and shortest occurrence of sustained torrential rains, which suggests that complicated terrain should not be favorable for the generation of sustained torrential rains.

Table 1 Statistics of the sustained torrential rains in the regions from 1958 to 2000

	Processes of rain	Total stations with record	Number of sustaining days	Number of stations by mean days/station
Reg.I	49	1 781	287	6.21
Reg.II	44	1 736	315	5.51
Reg.III	38	622	176	3.53
Sum	131	4 139	778	5.32

Table 2 Number of sustaining days for the torrential rains in the regions from 1958 to 2000

Number of days	3	4	5	6	7	8	9～15	>15
Reg.I	13	8	8	8	1	5	7	1
Reg.II	5	7	4	9	4	3	10	2
Reg.III	9	9	11	5	4	0	0	0
Sum	27	24	23	22	9	8	17	3

See the Chinese edition of the journal for more details.

3 SUMMARY

June is the month with the most frequent torrential rains and sustained torrential rains in the southern half of China, which bring especially tremendous damages to the areas south of the Yangtze River and South China. It is known from the statistical study that sustained torrential rains could simultaneously occur in the above two regions. The following conclusions can be drawn from the study of these rains over the 43-year period studied.

(1) The two types of torrential rains are much more frequently seen in Reg.I and Reg.II than in Reg.III while rarely recorded in low-latitude plateaus, e.g. the YGS Plateau, with complicated topography.

(2) As shown in the statistics, Reg.I and Reg.II are comparable in the number of stations recording the sustained torrential rains and the number of torrential rains that actually happen. It is by a rate of more than 40% for sustained torrential rains to take place

concurrently in both Reg.I and Reg.II. It is highly probable that torrential rains appear in both of the regions simultaneously.

(3) The 1990s is a time when sustained torrential rains are enhancing in all of the regions and dramatically in its late stage, which is responsible for a substantial increase of flooding destructions in the decade.

(4) It is known from the analyses of the three sustained torrential rains of June that there are usually two rain bands in the area south of the Yangtze River and South China: With the former rain band, low levels are usually south of a shear and north of a low-level jet stream while the latter rain band is mostly seen south of the center of a jet stream. At upper levels, the former rain band is usually affected by upper-level jet streams while the latter one is subjected to both the South Asia High and upper-level jet streams. The anti-Hadley cell of the South Asia High plays important roles in maintaining the latter rain band while the upper-level jet stream is the kinetic mechanism for maintaining the frontal zone over the area south of the Yangtze River. The stable and persistent South Asia High and upper-level jet streams are the main reasons for the generation of the double rain bands.

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