Study on Rainy Season Onset Time of the Longitudinal Range-gorge Region and Its Reasons

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Abstract: *The onset of rainy season is the period of spring groups planting in most regions of Yunnan Province, which has direct impact to agricultural production. Based on their daily precipitation of 2001 for time series, this study calculates the onset of rainy season of thirty meteorological stations in the Longitudinal Range-gorge Region in Yunnan Province. Taking the composite area of Wuliang Mountain and Ailao Mountain as a boundary line, rainy season onset of most stations are the sixth five-day of April or before in the eastern part, but ten or fifteen days later in the western. The reasons are demonstrated as follows. Firstly, there is a time difference between two vapours approaching to study area, the South China Sea summer monsoon onset is earlier than Indian summer monsoon. Secondly, the huge mountains, such as Wuliang Mountain and Ailao Mountain, have interception and barrier effect on the incoming vapors including the Bay of Bengal summer monsoon and the South China Sea summer monsoon. It acts on the water vapor transport of not only South China Sea summer monsoon from east to west, but also the Bay of Bengal summer monsoon from west to east in study area. In short, because of the interception and barrier of huge mountains effect on the incoming vapors, the composite area of Wuliang Mountain and Ailao Mountain becomes the boundary line of rainy season onset approaching in time difference, and is one of the dividing zones between the East Asia summer monsoon and the South Asia summer monsoon.*

Keywords: *rainy season onset time; monsoon system; interception and barrier functions; the composite area of Wuliang Mountain-Ailao Mountain*

The studies conducted by Chinese scientists have revealed that Asian monsoon is consisted of both southern Asian monsoon system and eastern Asian monsoon system that are interactive and also have their own independence [1]. The earliest eastern Asian monsoon outbreaks in the South China Sea usually at the middle 10 days of May and then gradually extends toward the west and the north whereas the south Asian monsoon usually outbreaks in the later 10 days of June [2]. Yunnan Province is located at the merger point of eastern Asian monsoon and the southern Asian monsoon and thus, is largely influenced by tropical system at the lower latitude. In the summer season, Yunnan Province is simultaneously influenced by both southern Asian monsoon and eastern Asian monsoon. But in the starting period of the rainy season in early summer, eastern Asian monsoon is the predominant one [3].

The detailed study results have indicated that the annual starting periods of the rainy season in Yunnan Province vary largely. In the normal years, the rainy season usually starts at fifth 5-day in May whereas in the abnormal years, the earliest start of the rainy season could be at the later 10 days of April whereas the latest start of the rainy season could be at the later 10 days of June. The earliest start and the latest start of the rainy season can differ by almost two months [4,5]. Because the earlier start or the later start of the rainy season in Yunnan Province is related to the industrial and agricultural productions, the starting period of the rainy season is of primary importance for the prediction of the short-term climate changes. Thus, studying on the starting period of rainy season in Yunnan Province is extremely important. The previous studies using the aerologic sounding data and outgoing longwave radiation data concluded that the rainy season in 2001 started at the early 10 days to the middle 10 days of May in a large majority of areas in Yunnan Province, which occurred 2-3 5-day earlier than that over the years, the precipitation in May in 2001 was higher even extremely higher. A rare flooding disaster took place in the earlier summer season [6]. In this study, we attempted to utilize the daily precipitation series data collected at meteorological stations that are commonly used in meteorological studies for calculating the starting period of rainy season and provided the geological explanation for the analyzed results.

1 The General Information about the Study Area

The study area is located at the south part of Yunnan Province. The administrative scope includes 30 administrative regions at the county-level in Yunnan Province, which are located between 98º40′53″~106º11′33″E and 22º26’34″~24º27’35″N and their total area is 101 900 km^2. The western part of study area belongs to the southwest mountainous areas of Yunnan Province, where Laobie Mountain, Bangma Mountain, Wuliang Mountain, and Ailao Mountain are vertically arranged in the mountainous highland. Among them, Ailao Mountain is a huge mountain longitudinally across northwest to southeast in the middle part of study area. The height of the major peak of this mountain range is higher than 3.1 km and is almost orthogonal to air current of the southern Asian monsoon. The regions located at the east of Ailao Mountain are neighbored by Yunnan Eastern Plateau through the separation of Yuanjiang River. The range of the topographical variations is relatively small. The study area is simultaneously influenced by the combined action of two tropical ocean moisture sources [7]. Especially, the western part located at southeast side of Tibetan Plateau is the compulsory route for southern Asian monsoon to enter into China. Climatically, there is an obvious alternation between the dry season and rainy season within a year in study area [8,9]. In the winter half year, this region is influenced by both west wind from South China Sea and plateau dry monsoon [10]. A part of this region is also influenced by eastern Asian winter monsoon. The climate is relatively dry and cold, and thus, is called dry season. In the summer half year, this region is controlled by both southern Asian monsoon and eastern Asian monsoon, the climate is relatively humid and hot, and is also called rainy season. That is to say, there are a variety of different landforms and topographies in study area and the climates there are complex and highly variable.

2 Research Methods

While there is an obvious rainy season in Yunnan Province, it is not easy to provide an objective and practical criterion for accurate determination of the start date of rainy season. Generally, the start date of rainy season can be determined from the status of agricultural production, weather situation and the changes in the monsoon circulation. A number of studies have been conducted on this field [4,11]. However, calculation of the standard for start date of rainy season using the relevant equation based on the precipitation data is commonly agreeable.

While it has been commonly believed that the period of May to October is the rainy season in Yunnan Province, there are variations in the start dates for the transition from the dry season to the rainy season in different regions and in the same region but in different years. The start date could be in the last 10 days of April, in May and even in the last 10 days of June. Thus, there are relatively large variations in the starting period of the rainy season. Based on the analysis described above, Qin et al. selected a standard equation (1) for the starting period of rainy season and used the starting period of rainy seasons in multiple years to calculate the start date. They obtained relatively accurate results as the follows: start from 21 of April to 30 of June, start from the date when the daily precipitation was ≥ three times that of the annual mean daily precipitation and the relative coefficient of precipitation (C) was ≥1 for concessive 5 days, 10 days and one month, then the first day was regarded as the start date of rainy season. The 5-day of this date is the start 5-day of rainy season, i.e.

$$C_N = R_N \div [(\overline{R} \div 365) \times N \qquad (1)$$

Where, C_N refers to the precipitation relative coefficient, it can be divided into 5-day, 10-day, and one month; R_N refers to the daily precipitation, $\overline{R}$ refers to the mean annual precipitation of multiple years.

3 Results and Analyses

3.1. The research results

The calculated results for the start date of the rainy season in 2001 with the data collected by 30 meteorological stations within this study area by using equation (1) were presented in Table 1. It can be seen that Ailao Mountain is the boundary for dividing the sub-regions with different start dates of rainy season as the follows. There are 16 meteorological stations, located nearby or in east of Ailao Mountain, whose rainy season onset time was earlier in the fifth 5-day in April. But the start date of rainy season of seven meteorological stations was later, in the second 5-day of May, which located in west of Ailao Mountain, including Yongde, Gengma, Lincang, Jinggu, Cangyuan, Shuangjiang, and Zhenyuan. In addition, several meteorological stations were special. Although Funing, Xinping, Honghe and Guangnan all located in east of Ailao Mountain, their rainy season onset time were the second 5-day of May, the first 5-day of May, the first 5-day of May and the sixth 5-day of April, respectively, calculated by using the equation (1). While Mojiang, Puer, and Zhenkang located at the west of Ailao Mountain, the start date of rainy season was the first 5-day of May, which was slightly earlier than that of the other neighboured meteorological stations in the west of Ailao Mountain. By making a general survey of the above analyses, it is clear that there are regular patterns for the start dates of rainy season gradually from the east to the west and from the south to the north. This conclusion is consistent with results made by Wang [12]. The conclusion made in this study that the start date of rainy season in 2001 is earlier than that of the normal years in the middle- and late-10 day of May is also basically consistent with the results made by Zheng et al. [6].

Tab.1 Rainy season onset time of thirty meteorological stations in study area of Yunnan Province

Onset time of rainy season	Meteorological Station Names
the fifth 5-day of April	Gejiu, Pingbian, Hekou, Qiubei, Jianshui, Shiping, Yuanjiang, Mengzi, Maguan, Wenshan, Xichou, Yanshan, Yuanyang, Lvchun, Jinping, Malipo
the sixth 5-day of April	Guannan
the first 5-day of May	Xinping, Honghe, Mojiang, Puer, Zhenkang
the second 5-day of May	Funing, Yongde, Gengma, Lincang, Jinggu, Cangyuan, Shuangjiang, Zhenyuan

3.2. Causal analyses

The results described above can be applied to provide a preliminary explanation based on the mean monthly precipitation data of multiple years in study area. These data were generated by using the Parameter elevation Regressions on Independent Slopes Model (PRISM) [13,14]. And were tested by using the multiple-year mean precipitation data collected from 31 meteorological stations that are independent from the meteorological stations in study area. The mean error was only 8.56% and the reliability of the analyzed results is relatively high [15].

It can be learn from the above analyses that there are two major water vapor sources for the precipitation in study area, i.e. southern Asian monsoon and eastern Asian monsoon. There are obviously temporal differences in their arrival time [16]. In term of the causes of these differences, researchers have conducted studies from multiple aspects, including the abnormality of ocean temperatures, the subtropical high pressure from the Western Pacific Ocean and the landform to investigate the causes. However, no commonly agreeable conclusions have been drawn to date [17]. Among the conclusions made to date, the one made by Wu et al. [18,19] is relatively convinced. These investigators thought that the actions of the thermal force and the mechanically forced convection of Tibetan Plateau led to the earlier entrance of an affluent of eastern Asian monsoon, the humid and hot air current from South China Sea, into study area than southern Asian monsoon did.

In the middle 10-day of April in 2001, the first entrance of an affluent of eastern Asian monsoon, originated from South China Sea, passed through the southeast corner of study area into the east of Ailao Mountain, which brought about a huge amount of water vapour and thus caused the formation of a huge amount of precipitation in the southeast regions of study area [20]. The precipitation reached 60-80mm, even in some regions, reached to higher than 200 mm. However, the precipitation in the west and north of the composite area between Wuliang Mountain and Ailao Mountain was lower than 50 mm (Fig. 1). With the time extended, another affluent started to invade into study area, whose name is South Asian Summer Monsoon, originated from Tropical Ocean and characterized by powerful force and rich vapour [21]. Immediately, the precipitation in the western part was rapidly increased and reached higher than 100 mm in a large majority region, even higher than 200 mm in south part of study area (Fig. 2). Until the middle and last 10-day of May, the whole study area all entered the rainy season. As the above described, the composite area of Wuliang Mountain and Ailao Mountain cause the barrier function to water vapour and lead to the formation of precipitation. Specifically, the study area in the last 10-day of April was only influenced by South China Sea Vapour, due to the interception and/or barrier function of Wuliang Mountain-Ailao Mountain, and its influence on the sub-regions west was very weak, so the eastern regions firstly came into rainy season. Until into May, when the Bay of Bengal Vapour began to invade study area, similarly, due to the interception and/or barrier function of Wuliang Mountain-Ailao Mountain, so the western regions quickly came into rainy season [22]. Then, the whole study area had come into rainy season before the middle 10-day of May.

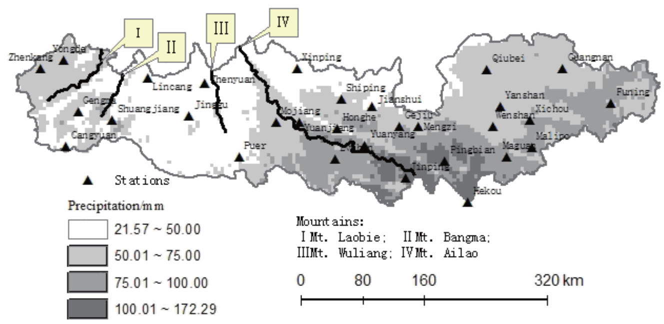

Fig.1 Spatial pattern of precipitation in April

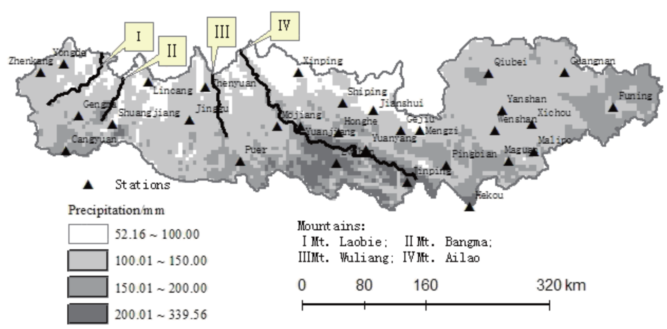

Fig.2 Spatial pattern of precipitation in May

In summary, the major reason for the clearly regional differences in the precipitation during April and May, when the winter monsoon is switched to the summer monsoon, is the existence of the temporal and phase differences in the arrival of water vapour between the eastern part and the western part of study area. And it is the barrier function to the water vapour by the landform of Wuliang Mountain-Ailao Mountain that is more important than the effects of different monsoon vapours.

4 Main Conclusions

The study area is characteristic of the longitudinal range-gorge region in Yunnan Province of China, including 30 meteorological stations. In this study, we used the daily precipitation series data of 2001 as the basic data and applied the rainy relative coefficient to calculate the start date of the rainy season, and then conducted detailed analyses on both April and May of precipitation spatial data. Three major conclusions were drawn as follows.

(1)There were significant regional differences in the start date of rainy season of 2001. In the regions located at the east of Wuliang Mountain-Ailao Mountain, the start date of rainy season was earlier and usually in the fifth 5-day of April whereas in the regions located at the west of Wuliang Mountain-Ailao Mountain, the start date of rainy season was usually in the second 5-day of May.

(2)These differences are mainly due to two reasons. The first reason is that there existence of the temporal and phase differences in the arrival of vapour between the east part and the west part of study area; and the second reason is the interception and barrier function to the vapour by the landform of Wuliang Mountain-Ailao Mountain.

(3) The combined landform of Wuliang Mountain-Ailao Mountain not only becomes the boundary for the regional differences in the start date of rainy season in Yunnan Province, but also is one of the boundaries for eastern Asian monsoon and Southern Asian monsoon.

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