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Climatic Characteristics of Different Time Scales of Meiyu Precipitation in Shanghai

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Abstract: Based on the daily precipitation data of 10 national stations and regional stations in Shanghai from 1960 to 2020, the temporal and spatial distribution characteristics of Meiyu season precipitation in Shanghai and the climatic characteristics of Meiyu season precipitation in Shanghai were analyzed. The first mode PC of EOF was used to correlate with 500hPa, 850hPa height field, 850 specific humidity field and wind field to analyze the temporal and spatial distribution characteristics of Meiyu season precipitation in Shanghai and the physical quantity field variation law of climatic state change. The results show that the temporal variation trends of annual precipitation and accumulated precipitation in Meiyu season in Shanghai are similar, and there are interannual and interdecadal variations. The inter-decadal precipitation showed an obvious upward trend. The regional distribution of average precipitation during Meiyu period in Shanghai is complex and variable, but at the same time, the distribution shows a certain difference between the north and the south. There are interdecadal and interannual trends in the maximum cumulative precipitation per day, the number of rainy days in the Meiyu season, the maximum cumulative rainfall for five consecutive days at a single station, and the longest continuous rainfall days at a single station. From the perspective of interdecadal changes, except for individual interdecadal changes, the overall trend is upward, there are mainly 2-8 years of periodic oscillations. The subtropical high maintains between South China and the middle and lower reaches of the Yangtze River. The high-latitude low-pressure system is active. The conditions of high specific humidity in the southeast coastal area and low specific humidity in the inland, high relative humidity in the coastal area and low relative humidity in the inland are conducive to the increase of Meiyu season precipitation in Shanghai. The most favorable zonal wind condition for the precipitation in Shanghai during the Meiyu season is that Shanghai is located on the north side of the subtropical high, and the westerly jet strengthens. The reason for the increase of precipitation in Shanghai in July and August is not only the Meiyu precipitation, but also some interference under extreme circulation conditions. The southerly wind to the south of Shanghai and the northerly wind to the north strengthened, and the north-south cold and warm air converged in Shanghai, which directly increased the precipitation in the Meiyu season in Shanghai.

1. Introduction

Plum rain is a unique weather and climate phenomenon in East Asia, which is a weather and climate phenomenon unique to the middle and lower reaches of the Yangtze River in China. It basically occurs in the Jianghuai River basin of China, from the middle and lower reaches of the Yangtze River in China, to 28-34 °N east of Yichang, to the narrow area of southern Japan from the middle of June to the middle of July, a period of continuous rainy weather. At this time, when the Jiangnan plum mature, so also called "plum rain" or "Huangmei rain"; and because of the high air humidity, high temperature, the utensils are easy to mold, so also called "mildew rain". After the middle of June, the rain belt is maintained in the Jianghuai River basin, which is the plum rain. The climate characteristics of plum rain are rainy weather in the middle and lower reaches of the Yangtze River, with abundant rainfall, high relative humidity, short sunshine time, and precipitation is generally continuous, but there are often showers or thunderstorms, sometimes reaching the degree of rainstorm. The influence of plum precipitation on the Jianghuai region from June to July is extensive, and its development and changes reflect the circulation situation over eastern Asia from late spring to midsummer. Due to the influence of topography and climate, the Jiang-huai River Basin is prone to floods in China, mainly occurring in June to August. The precipitation during the plum rain period is closely related to the occurrence and persistence of early waterlogging disaster in the Jianghuai area. Shanghai is located in the middle and lower reaches of the Yangtze River in China, which belongs to the Jianghuai River basin, and is deeply affected by the plum rain and precipitation. Therefore, it is of great significance to study the precipitation in Shanghai.

At present, many scholars have studied a lot of analysis of various themes of plum rainy season, mainly in the formation mechanism, influencing factors, yield characteristics of rainy season, drought and flood [1-4]. The study shows that the formation reason of plum rain is mainly due to the obstruction of high pressure or stable high pressure ridge in the middle of the high latitude convective zone in Asia. In the middle latitude region, a flat west wind circulation conducts frequent shortwave activities to transport cold air to the Jianghuai region. The western Pacific subtropical high has a process of obvious westward extension and north jump, which makes the 500 hPa subtropical high ridge line stable between north latitude 20 degrees and 25 degrees, conveying the warm and humid air flow from the edge of the subtropical high to the Jianghuai River basin. Under this circulation condition, the Meiyu front formed by the cold and central air mass lingers in the Jianghuai River basin, often accompanied by the southwest vortex and shear line, and is active in the mesoscale system on the Meiyu front. It not only causes the continuous precipitation during the plum rain period, but also provides abundant water and gas conditions for the rainstorm [5]. As early as the 1930s, Chinese meteorologists conducted research [6] on all levels of Meiyu. Research on the formation mechanism of plum rain shows that the main influencing factor of plum rain is the 500pa high altitude meteorological element [7-12]. Therefore, many scholars identify the regional Meiyu from the perspective of atmospheric circulation characteristics and precipitation during the Meiyu period. For example, Wu Guangren et al. [13] studied the relationship between rainy precipitation and the global 500 hpa circulation in the middle and lower reaches of the Yangtze River, and Yang Guangji et al. [14] studied the relationship between persistent drought and flood and the prevalence of low-latitude tropical rings in the middle and lower reaches of the Yangtze River basin. These studies have a wide range and mainly focus on the problem of circulation situation. However, the climate characteristics of precipitation are less studied. There are many scholars using different methods to study the problem of Shanghai rainy period precipitation, such as ma yue [15] using space-time projection method studied the area of Shanghai plum flood season precipitation extension period forecast and use the application of EOF first mode PC, and environmental height field, humidity field, wind field time series correlation analysis, get correlation coefficient distribution, to find out the environmental variables of Shanghai rainy precipitation. Therefore, the study on different time scale climatic characteristics of plum rain precipitation in Shanghai can provide new cognition and more accurate understanding of plum rain and precipitation in Shanghai.

Since the 21st century, due to the global climate warming, it has directly affected the water circulation system of the whole earth, greatly increasing the frequency of extreme disaster weather such as drought and flood. At the same time, China has a broad region, various landforms, different regions have different climatic conditions, and significantly uneven spatial and temporal distribution. Under the influence of the circulation situation, the Jianghuai River basin is located in eastern China, and the precipitation in the rainy season in June and July is prone to abnormal occurrence, leading to frequent drought, flood and other disastrous weather. As a more important city in China, Shanghai is also a city greatly affected by the plum rain climate. The length of the annual plum rain period, the time of the plum season, and the precipitation during the plum rain period actually affect our daily life, agricultural farming, urban infrastructure construction and other necessary work. Therefore, the study of the climate characteristics of precipitation in Shanghai can bring some help to the flood control and drought relief work in Shanghai, and provide new ideas for the prediction of precipitation in the rainy season in Shanghai.

2. Data Sources

From the China Meteorological Data Network (http: / / data.cma. Cn /), daily precipitation data of 10 national stations and regional stations in Shanghai from 1960 to 2019. In order to maintain the data continuity, 10 stations built before 1960 were selected, namely Minhang, Baoshan, Jiading, Chongming, Xujiahui, Nanhui, Jinshan, Qingpu, Songjiang and Fengxian. The distribution is shown in Figure 1. It can be seen that the available sites in the west of Shanghai are more dense in the east, and the northern sites are also relatively rare.Background field data are global atmospheric reanalysis data jointly developed by the National Center for Environmental Forecasting (NCEP) and the National Center for Atmospheric Research (NCAR)[16], Including the monthly average data of 500 hPa and 850 hPa height fields, and 850 hPa, with a spatial resolution of 2.5 °x2.5 °.

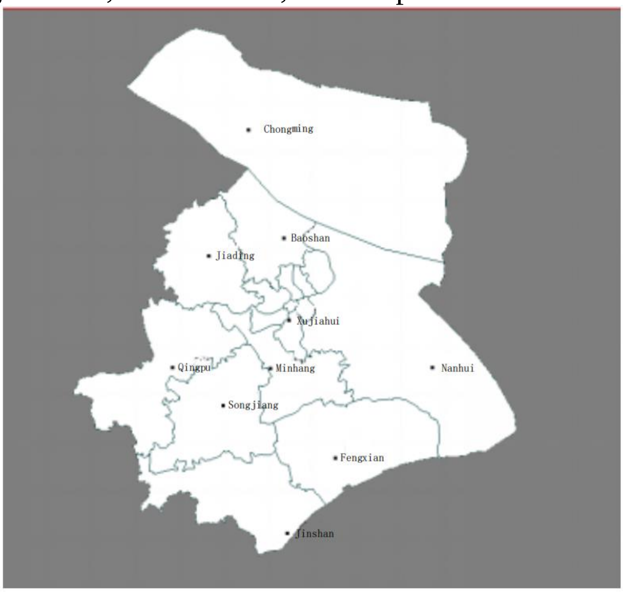

Figure 1: Distribution map of the study sites

3. The spatial and temporal changes of plum rain precipitation in Shanghai

3.1 Time variation pattern of precipitation

The analysis of annual precipitation can reflect the interannual and interage changes of precipitation in the exit area. First of all, the daily precipitation data of Shanghai from 1960 to 2020 were used to analyze the annual cumulative precipitation of Shanghai in the past 70 years (Figure 2). The average annual cumulative precipitation of the 10 stations in Shanghai was about 11500 mm, the year with the most precipitation was 1999, the annual precipitation was 16907.8 mm, the year with the least precipitation was 1978, and the annual precipitation was 6685.4 mm. By analyzing the time trend, we can see that the annual and chronological precipitation in Shanghai varies annually. From the perspective of the interannual change of annual precipitation, the annual precipitation in Shanghai has a cycle shock of 2-8 years, and this interannual change is the most significant at the end of the 20th century. Based on Mann Kendall test (figure omitted), the annual precipitation mutation in Shanghai occurred around 2000, and after 2000, the annual precipitation increased significantly and maintained at a high level.

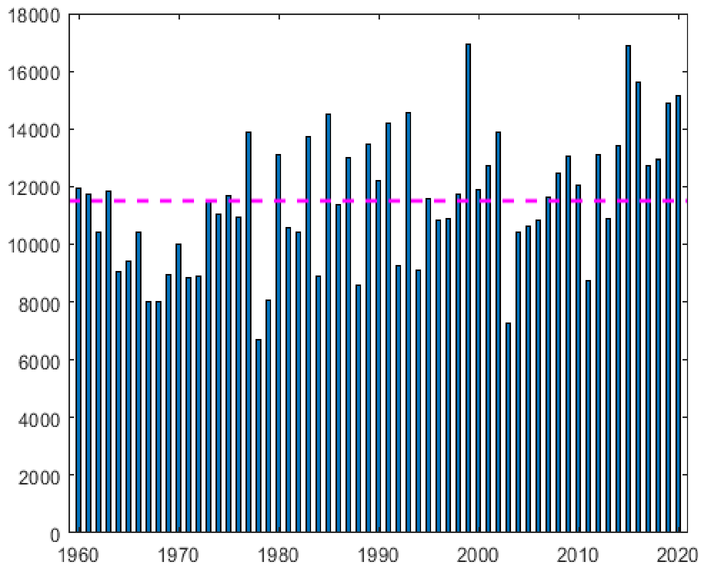

Figure 2: Annual precipitation and average value of Shanghai from 1960 to 2020 (where the dotted line represents the average frequency value)

Due to the east Asian summer monsoon, there is an obvious plum rain period in Shanghai. In this study, the precipitation in July and August is selected to study the temporal and temporal variation law of the plum rain period in Shanghai. Using Shanghai in July 1960-2020 and August 10 station daily precipitation data of Shanghai nearly 70 years of rain precipitation analysis (figure 3), rain season cumulative precipitation average above 3100 mm, Shanghai nearly 70 years rain precipitation and precipitation time change rule is similar, that the precipitation and change on the change of annual precipitation law has important influence. The year with the most precipitation in Shanghai was also 1999, and the precipitation during the plum rain period was 7525.3 mm, about 2.4 times the average precipitation during the plum rain period in the past 70 years. The year with the least precipitation was 1968, and the precipitation during the Meiyu period was 1227.1 mm. The analysis of the time change trend can also see that there are inter-annual and chronological changes in the precipitation in Shanghai. From the perspective of the annual precipitation during the plum rain period, there is a certain inter-annual change trend in the precipitation during the plum rain period in Shanghai, and there is a periodic shock of 2-8 years.

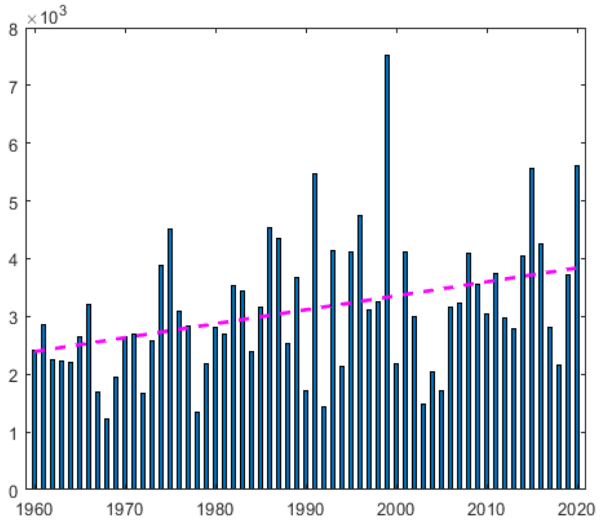

Figure 3: Annual precipitation and one-dimensional linear fitting in Shanghai plum rainy season (June and July) from 1960 to 2020

3.2 Precipitation and change and shock cycle in Shanghai plum rainy season

According to the cumulative precipitation of 10 Shanghai stations in the rainy season in 61 years (map omitted), although Shanghai is a plain area, there are still differences in spatial precipitation. The largest precipitation is Xujiahui station, followed by Chongming Station, and the smallest. The overall spatial distribution is more in the north and less in the south.

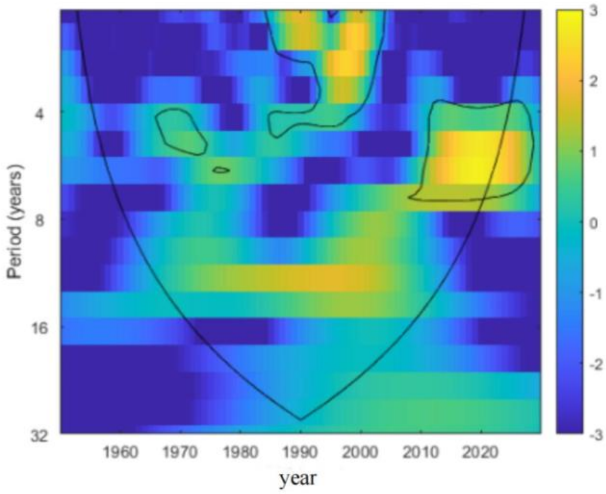

Figure 4: Wavet analysis power spectrum

Shanghai plum rainy season precipitation changes year by year for wavelet analysis, remove the overall trend of higher precipitation, there are different time cycle fluctuations, wavelet analysis power spectrum as shown in figure 4, abscissa said year, ordinate characterization of shock cycle, the upper image for high frequency changes, the lower part of low frequency changes, black line area for more than 95% confidence. Among them, there are three effective areas with high confidence, all of which occur in the interannual changes of less than 10 years, which is the main change cycle of precipitation in the plum rainy season in Shanghai. The first high-confidence region before 1980, occurring around 1970, has a wavelet energy value of 1, reflected by fluctuations in 4-6-year cycles. Between 1980 and 2000, a second high confidence region appeared, and the oscillation period shortened to 2-4 years, but the energy gradually increased to a maximum energy of 3 at the end of the 20th century, which was be due to the strong El Nino event in 1997. After 2000, the shock cycle was extended again, showing the third high confidence region of a 4-8-year cycle between 2010 and 2020, and its energy also reached more than 3. At the same time, we can also see that from 1970 to 2010, there was a 10-12 year period change, and the energy also reached more than 2. However, due because the time series is not long enough, the cycle change may not be very typical, and failed to pass the 95% confidence test. Therefore, the precipitation in the rainy season in Shanghai is the superposition of multiple time scale cycle changes, with the most obvious inter-annual changes and the cycle shocks of 2-8 years, and the inter-period change between 10-12 years. The plum rain precipitation is consistent with the changes of ENSO and SST. Later, we will make further analysis and diagnosis of the factors that cause the change.

3.3 Spatiotemporal variation law of precipitation

In order to study the temporal and spatial variation characteristics of the average precipitation during the plum rain period in Shanghai, the average precipitation from 1960 to 2020 was naturally experienced orthogonal development (EOF). The first two modes both passed the 95% confidence test, with the explained variance of the first mode contributing 12.5%. Therefore, the first mode can characterize the main characteristics of Shanghai Meiyu, and the first two modes can basically comprehensively reflect the spatial distribution characteristics of the average precipitation in Shanghai Meiyu period. Therefore, this paper will mainly analyze the first two modes of EOF expansion of average precipitation in Shanghai.

Figure 5 shows the distribution of the eigenvector fields corresponding to the first two modes of the natural orthogonal expansion of the average precipitation from 1960 to 2020 (the yellow line is the nine-point sliding average of the time coefficient). The first mode feature vector field variance contribution rate is 92%, can be seen from figure 5 (a), Shanghai plum rain average precipitation of the first characteristic vector field of the spatial distribution of the whole characteristics, and present the southern numerical distribution characteristics of Shanghai, the northern basic around 150 mm, the southwest numerical minimum, basic below 100 mm. This indicates that compared with the southern part of Shanghai, the change of the average precipitation during the rainy period is more obvious, while the change in other regions is weaker, especially the precipitation in the southwest of Shanghai. As shown in Figure 5 (b), the second eigenvector field shows a trend opposite from north to south, negative in the north, basically between-40 mm and-20 mm, positive in the south, between 0 mm and 60 mm, and increasing from northwest to southeast. This shows that the average precipitation in the plum rainy season in Shanghai shows the distribution characteristics of the north-south reverse phase.

In general, the first two modes of the natural orthogonal expansion of the average precipitation in Shanghai are somewhat different from each other, which represent the different climatic characteristics of the spatial distribution of the average precipitation during the Meiyu period in Shanghai. It also shows that the regional distribution of average precipitation in the Meiyu period in Shanghai is complex and variable, but at the same time, it presents a common characteristic. The regional distribution of average precipitation in Shanghai shows a trend of difference between the north and the south. This shows that the average precipitation in the south and north of Shanghai is different.

Figure 5 (c) and 5 (d) show the sequence diagram of the first and second modal time coefficient of the average precipitation in Shanghai from 1960 to 2020. From Figure 5 (c-d), the time coefficient of the first mode shows very obvious inter-year and chronological changes. The time coefficient of the first mode is smoothed by 9 points to obtain the age change. It can be seen that the reverse phase was weak before 1970, the positive phase between 1970 and 2000, and then the weak reverse phase after 2000. From the perspective of interannual change, there is a phase conversion of 2-4 years. Combined with the spatial distribution, we found that before 1970, the precipitation in most areas of Shanghai showed a trend of less, and the precipitation trend of less in the north was more obvious. From 1970 to 2000, the average precipitation in most areas of Shanghai showed more trend, and the trend in the north was more obvious than that in the south. After 2000, the precipitation in most areas of Shanghai showed a trend of a small amount, and the less was more obvious in the north. Among them, the time coefficient in 1999 was the largest, close to 4, indicating that the precipitation in 1999 was significantly more.

The range of time coefficient variation of the second mode is small relative to the first mode, ranging between-2mm-2mm, the reverse phase is larger relative to the first mode, some years below-2mm, there are significant inter-annual fluctuations. The second mode, except for some years, the time coefficient was mainly negative before the 1980s, while from 1980 to 200 0, mainly positive, and after 2000, mainly the reverse phase. It shows that in most years before the 1980s, precipitation in the north of Shanghai was more than that in the south, and the southeast was the most obvious. In most years from 1980 to 2000, precipitation in the north of Shanghai was less than that in the south, and the southeast was the most obvious. In most years after 2000, precipitation in the north of Shanghai was more than that in the south. Less precipitation in the southeast was the most obvious.

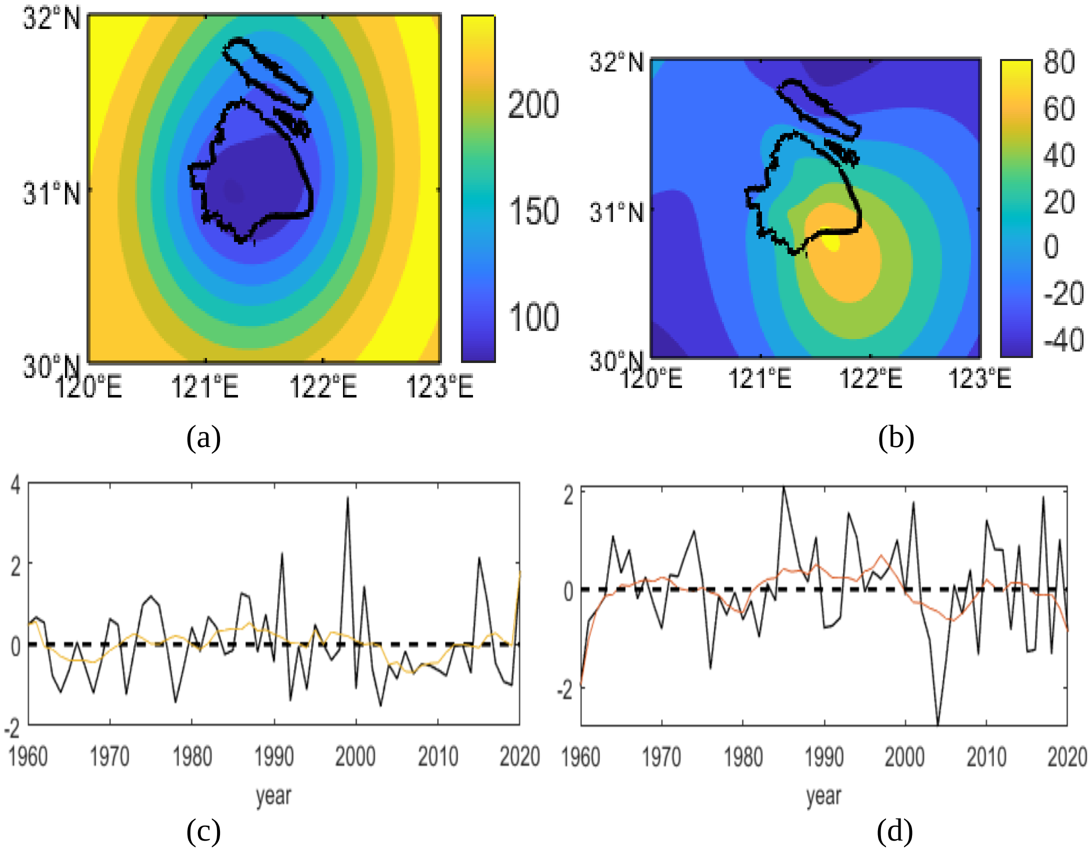

Figure 5: EOF first (a) and second (b) modes of average precipitation in Shanghai in 1960-2020 The second (d) modal time coefficient seri

4. Climate characteristics of precipitation in plum rainy season in Shanghai

The time change of the maximum cumulative precipitation in the plum rainy season and the precipitation days of the plum rainy season and the maximum cumulative rainfall shows the change trend of the extreme characteristics of the plum rain in the plum rainy season. This paper calculates the maximum cumulative precipitation of precipitation in the plum rainy season, the maximum cumulative rainfall of 5 consecutive days in a single station (Figure 6), so as to analyze the climate characteristics of precipitation in the plum rainy season in Shanghai.

Using the daily precipitation data from 1960 to 2020, the maximum daily cumulative precipitation in all the plum rainy season in Shanghai is analyzed (Figure 6a), and the average maximum daily cumulative precipitation in the plum rainy season in Shanghai is about 543.4 mm. The year with the maximum daily cumulative precipitation in the rainy season was also 1999, which is the same as the maximum annual precipitation in Shanghai and the maximum year. The daily precipitation reached 1175.1 mm, about 2.2 times the average daily cumulative precipitation in the rainy period in the recent 70 years. The year with the lowest daily precipitation was 1968, which is the same as the lowest cumulative precipitation in Shanghai plum rainy season, with the maximum daily precipitation of 146.5 mm. The analysis of the time change trend can also see that the interannual and chronological changes of the daily maximum precipitation in Shanghai. In addition to the first 10 years of the 21st century, the decadal maximum single-day precipitation basically showed an obvious upward trend. From 1960 to 1969, the maximum single-day precipitation in Shanghai was about 456.3 mm, which was lower than the average maximum single-day precipitation in the last 70 years of Meiyu period in Shanghai; From 1970 to 1979, the maximum daily precipitation in Shanghai area was about 483.1, It is lower than the average one-day precipitation in Shanghai in nearly 70 years; From 1980 to 1989, the average one-day precipitation in Shanghai was 531.5 mm, basically the same as the average one-day precipitation in Shanghai in the past 70 years; 1990-1999 Shanghai average daily precipitation was 644.6 mm, It is higher than the average one-day precipitation in Shanghai in nearly 70 years; From 2001 to 2009, the maximum daily precipitation in the Meiyu period was 472.8 mm, It is lower than the average daily maximum precipitation during the plum rain period in Shanghai in the past 70 years; From 2010 to 2020, the average annual maximum daily precipitation in Shanghai area is 660.3 mm, It is higher than the average daily precipitation in the rainy period in the past 70 years. From the perspective of the annual daily maximum precipitation in the plum rain period, there is a certain inter-annual change trend of the daily maximum precipitation in the plum rain period in Shanghai, and there is a cycle shock of 2-8 years.

Analyzing the precipitation days of all plum rainy season in Shanghai (Figure 6b), the average precipitation days of plum rainy season in Shanghai from 1960 to 2020 are about 25.8 days. The year with the largest number of precipitation days in the rainy season is 2020, and the precipitation days reach 38.7 days, which is about 1.5 times that of the precipitation days in the rainy period in the past 70 years. The year with the least precipitation days was 1967, and the precipitation days were 16.9 days. The analysis of the time change trend can also see that the interannual and chronological changes of the daily maximum precipitation in Shanghai. The number of days of the rainy season increased from the 1960s to the 1980s, decreased slightly from the 1990s to the 2910s, and increased again in the 2020s.1960-1969 in Shanghai area of precipitation days of about 21.8 days, it is lower than the average precipitation days in Shanghai in recent 70 years; the precipitation days in Shanghai from 1970 to 1979 were about 26.8 days, it is similar to the average precipitation days in Shanghai in the recent 70 years; from 1980 to 1989, the average precipitation days in Shanghai was 28.4 days, slightly higher than the average precipitation days in Shanghai in the recent 70 years; the average number of precipitation days in Shanghai from 1990 to 1999 was 26.0

days, slightly higher than the average precipitation days in Shanghai in the past 70 years; the precipitation days in Shanghai from 2001 to 2009 were 23.5 days, lower than the average precipitation days in Shanghai in the past 70 years; the average annual days of precipitation in Shanghai from 2010 to 2020 was 28.3 days, it is higher than the average precipitation days in Shanghai in the recent 70 years. From the perspective of the annual precipitation days, there is a certain inter-annual change trend of the precipitation days in Shanghai, and there is a cycle shock of 2-8 years.

In this study, the maximum cumulative rainfall for 5 consecutive days in the rainy season in Shanghai (Figure 6c) was analyzed, and the average maximum cumulative rainfall in the rainy season from 1960 to 2020 was about 167.3 mm. In the rainy season, the maximum cumulative rainfall for 5 consecutive days was in 2001. The maximum cumulative rainfall of a single station for 5 consecutive days reached 337.6 mm, which was about twice the maximum cumulative rainfall of a single station for 5 consecutive days during the rainy period in the past 70 years. The year with the least maximum cumulative rainfall in a single station for 5 consecutive days is 1968, which is the same as the cumulative precipitation in Shanghai plum rainy season and the minimum maximum precipitation in plum rainy season. The maximum cumulative rainfall in a single station for 5 consecutive days is 46.7 mm. The analysis of the time change trend can also be seen that the interannual and chronological changes of the maximum cumulative rainfall in Shanghai for 5 consecutive days. The maximum cumulative rainfall of a single station for five consecutive days showed a decline from the 1960s to the 1970s, slowly recovered in the 1980s, increased rapidly in the 1990s, decreased again in the 201 0s, and increased rapidly in the 2020s. From 1960 to 1969, the maximum cumulative rainfall of a single station in Shanghai area for five consecutive days was about 160.2 mm, slightly lower than the average maximum cumulative rainfall of a single station for 5 consecutive days in Shanghai during the plum rain period in the past 70 years; from 1970 to 1979, the maximum cumulative rainfall of a single station in Shanghai area for 5 consecutive days was about 143.6, it is lower than the average of Shanghai in the past 70 years; From 1980 to 1989, the average cumulative rainfall of a single station in Shanghai for 5 consecutive days was 159.3 mm slightly lower than the average cumulative rainfall of a single station for 5 consecutive days in Shanghai in the past 70 years; from 1990 to 1999, the maximum cumulative rainfall of the average single station for five consecutive days was 194.6 mm, it is higher than the average maximum cumulative rainfall of a single station for 5 consecutive days in Shanghai in the past 70 years; from 2001 to 2009, the maximum cumulative rainfall of the single station in Shanghai for five consecutive days was 160.4 mm, it is lower than the average maximum cumulative rainfall in Shanghai in the past 70 years; from 2010 to 2020, the average annual maximum cumulative rainfall of Shanghai single station for five consecutive days is 184.1 mm, it is higher than the average maximum cumulative rainfall of the plum rainfall period in Shanghai in the past 70 years. From the perspective of the maximum cumulative rainfall of 5 consecutive days in the annual plum rainfall period, the maximum cumulative rainfall of the annual plum rainfall period in Shanghai has a certain interannual change and mutation trend, especially the most obvious mutation around 2000.

Using the daily precipitation data from 1960 to 2020, the number of longest continuous rainfall days for single station in plum rainy season in Shanghai was calculated (Figure 6d), and the average number of longest continuous rainfall days for single station in plum rainy season in Shanghai was about 6.8 days. In the rainy season, the longest continuous rainfall days of a single station was in 1969, reaching 13.3 days, which was about twice the longest continuous rainfall days of a single station in the past 70 years. The year with the least longest continuous rainfall days in a single station was 2004, and the longest continuous rainfall days in a single station was 3.9 days. By analyzing the time change trend, we can also see that the longest continuous rainfall days in a single station in Shanghai change. S single station the longest continuous rainfall days in the 1960s to the

1970s, slowly rebound in the 1980s, increased rapidly in the 1990s, again in the 21010s, the 2020s, trend and plum rain period single station five consecutive days maximum cumulative rainfall is similar. From the perspective of the maximum daily precipitation in the annual Meiyu period, there is a certain annual change trend in the longest continuous rainfall day of the single station in Shanghai, and there is a cycle shock of 2-8 years.

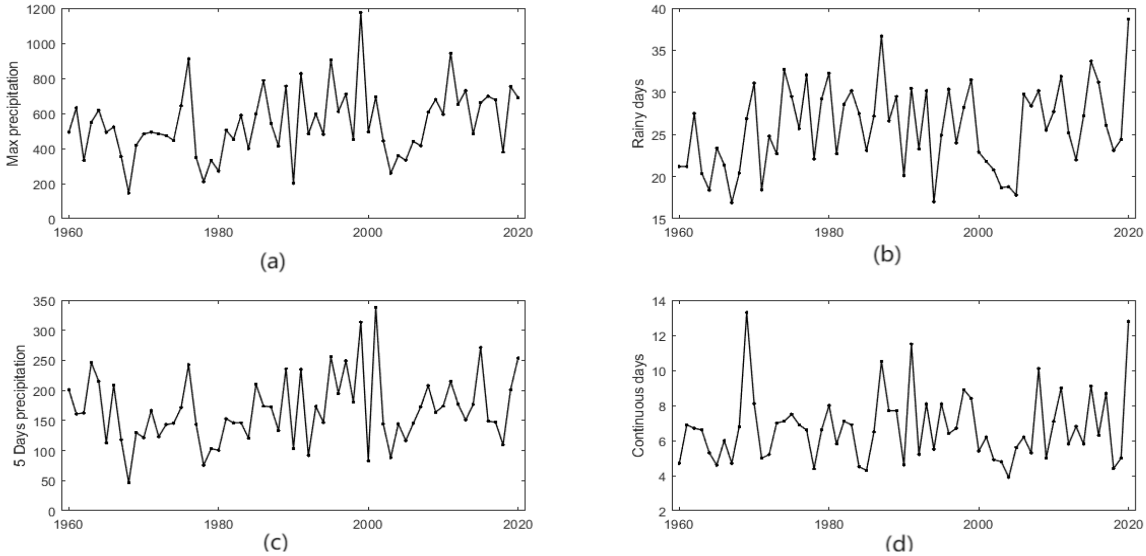

Figure 6: Maximum daily cumulative precipitation (a), precipitation days in plum rainy season (b) from 1960 to 2020 in Shanghai Maximum cumulative rainfall days for 5 consecutive days (c) and number of longest continuous rainfall days in a single station (d)

5. Analysis of the precipitation environment field in the plum rainy season in Shanghai

From the principal component analysis, the first EOF mode reflects the spatial and temporal distribution characteristics of Shanghai plum rain precipitation, so this paper using the first mode PC, and environment height field, humidity field, wind field time series correlation analysis, correlation coefficient distribution, so as to find out the influence of environmental variables on Shanghai plum rain precipitation mechanism. In the first mode, when the PC is in positive phase, the total precipitation in the rainy season in the city increases, and when the environmental field is positively correlated with the PC, the positive deviation in the environmental field increases in Shanghai, and the negative deviation in the environmental field decreases the precipitation with the PC.

5.1 Height field

The altitude field mainly uses 500 hPa and 850 hPa altitude fields to characterize the large scale weather system and low altitude dynamic conditions that affect the precipitation in the plum rainy season.

As can be seen from the distribution map of the correlation coefficient between 500 hPa height field and PC (Figure 7a), the subtropical high and east Asian high latitude low value system are the main factors affecting the precipitation in the rainy season in Shanghai. The subtropical high between 15 °N to 30 °N, positively correlated with PC, positive correlation region from southwest China to the northwest Pacific Ocean, and gradually increasing, so when the subtropical high strong, namely the 500 hPa field in the area than the perennial high, corresponding to the PC phase, will lead to Shanghai plum rainy season precipitation, especially the precipitation in southern Shanghai.

However, in the year of weak subtropical high, the 500 hPa height field in this area is lower than the usual year, corresponding to the negative phase of PC, which is manifested by the decrease of precipitation in the rainy season in Shanghai. Another influence Shanghai plum rainy season precipitation weather scale circulation field north of 35 °N high latitude low pressure system, it and PC field is obvious negative correlation, area between Lake Baikal to Bering channel, the strongest is located in 40 °N north of northeast China and west of the region, when the low pressure system is active, namely 500 hPa height field is lower than all the year round, corresponding to the PC positive phase, is conducive to the Shanghai plum rainy season precipitation increased circulation situation, and high latitude low pressure system is relatively stable years, corresponding to the PC negative phase, make Shanghai plum rainy season precipitation reduced. Through the analysis of large scale circulation system, the subtropical high in south China and the middle and lower reaches of the Yangtze river, Shanghai is located in subtropical high peripheral, plum rain rain belt on Shanghai time extension, cause plum rain precipitation increase, and high latitude low pressure system active, will send cold air, south and the south warm wet air mass interchange, also can lead to the plum rainy season precipitation in Shanghai area.

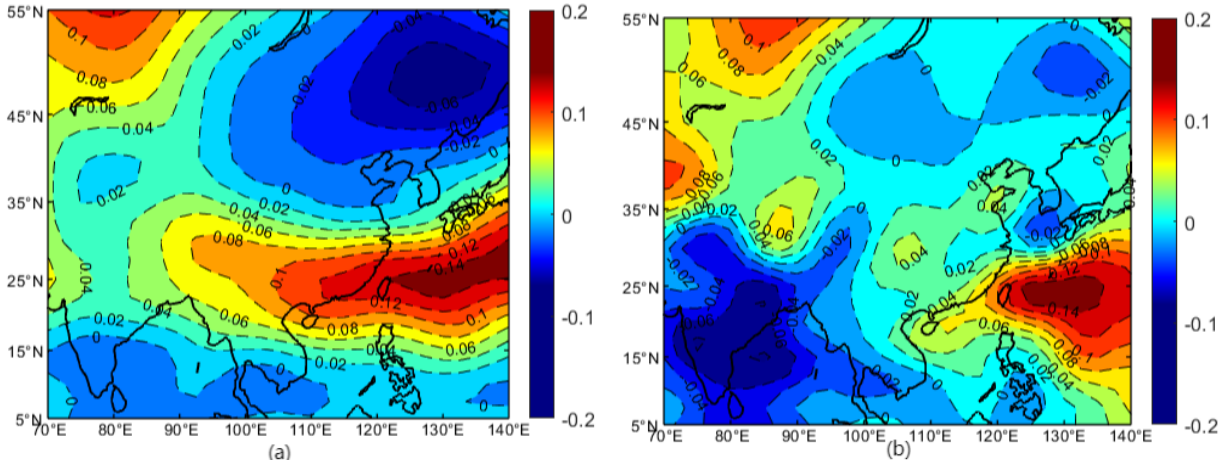

Figure 7: High field correlation coefficients for pc 1 and 500 hPa and 850 hPa

The low altitude system is usually the weather background of small and medium scale convective precipitation. Due to the low altitude in Shanghai, we can observe the influence of 850 hPa altitude field on the local precipitation. By 850 hPa height field and PC correlation coefficient distribution chart (figure 7b), and the most direct Shanghai plum rainy season precipitation is still the subtropical high pressure system, compared to 500 hPa height field, its position is more east, and the scope is small, the main area for the northwest Pacific east of Taiwan island area, it also characterized the subtropical high is very deep, therefore, when the northwest Pacific 850 hPa high pressure strong year, corresponding to the PC positive phase, will make Shanghai plum rainy season precipitation increased. However, the local 850 hPa height in Shanghai does not have a high correlation with the sequence of plum rain precipitation, so the local precipitation does not lead to the interchronological change of plum rain, which is mainly related to the movement of the plum rain belt. Also found that the low pressure on the Indian peninsula system and Shanghai rain precipitation is a phase, previous studies known, the southwest of the southern Indian Ocean monsoon, the formation of low jet can bring precipitation to southwest China and south China, our research shows that India low pressure also affect precipitation in east China. The two systems with the highest correlation between the 850 hPa altitude field and the precipitation in the plum rainy season in Shanghai are the deep subtropical high and the strong Indian depression, while the middle and high latitudes have little influence on them.

5.2 Humidity field

Water vapor condition is a necessary condition for precipitation generation. When analyzing the humidity field, the specific humidity field and relative humidity field on the 850 hPa isopressure surface are calculated, which shows the moisture content in the lower layer and the relative humidity and the saturation degree of the air in the lower layer.

The correlation coefficient between the specific humidity field of 850hPa isobaric surface and PC is calculated, and the distribution is shown in Figure 8a. It can be seen that in the years with more precipitation in Shanghai plum rainy season, the most significant region is the middle and lower reaches of the Yangtze River with higher specific humidity and abundant water vapor, and the water vapor content is not only higher in the areas around Shanghai. In the whole period between 15 °N-30 °N, the specific humidity around the Indian Ocean to the north of the southeast coast of China is positively correlated with PC, which indicates that not only the local water vapor conditions are good, but also the southeast and southwest paths are continuously transporting water vapor. Only when the water vapor in the air condenses continuously, the precipitation could be maintained for a long enough time, and the accumulated precipitation could be increased. In addition, in the years with abnormal rainfall in the middle and lower reaches of the Yangtze River, the moisture in inland China is lower than that in the previous year. Because the rain belt is lower and the precipitation of North China is low in the coastal areas, the inland moisture value is lower. However, when more water vapor is transported to the inland, the condensation precipitation is lower between the wet field in inland China and the plum rain in Shanghai. Therefore, the peak year of Meiyu in Shanghai corresponds to the year of higher humidity value in southeast coastal areas and the year of lower humidity value in inland. The main source of precipitation in plum rainy season in Shanghai is the transportation of water vapor from the Yangtze River to southeast and southwest.

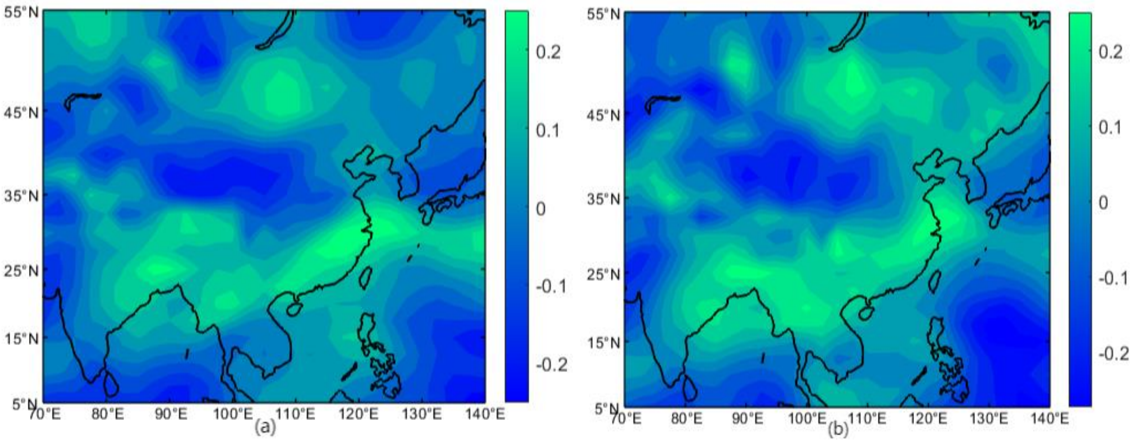

Figure 8: Wet field and relative humidity field correlation coefficient between pc 1 and 850 hPa

The correlation coefficient distribution of the relative humidity field of the 850 hPa surface and PC (Figure 8a) is similar to the specific humidity field distribution, and there is also an obvious positive correlation in the southeast coastal areas, indicating that the air saturation in this area is high and the number of precipitation can occur, which increases the precipitation in the plum rainy season in Shanghai. But there are still some differences, relative humidity and the highest correlation is PC area in north of Shanghai, possible reason is that the regional average relative humidity is lower than south China coast, south of Shanghai area relative humidity is high as a whole, not sensitive to the outside world, and relative humidity is not only affected by the net content of water vapor in the air, also related to temperature, high latitude low pressure system of cold air will lead to the increase of relative humidity. On the whole, the high relative humidity in low latitude coastal areas and the low relative humidity in inland areas correspond to the years with more precipitation in the rainy season in Shanghai. The increase in the relative humidity in the Jianghuai River basin north of Shanghai has the greatest impact on the precipitation in Shanghai, indicating that the precipitation in Shanghai is not only affected by humidity, but also controlled by temperature.

Low-altitude wind field can not only reflect the dynamic conditions of atmospheric circulation, but also transport water vapor for precipitation. At the same time, the warm and wet air transported increases the instability of the atmosphere, especially the left front of the low-altitude jet is very prone to heavy rain.

Analysis of 850 hPa pressure of latitude wind field and PC correlation coefficient distribution (figure 9a), you can see the south of Shanghai westerly increment and 15 °N near the Malay islands Dongfeng increment and PC positive correlation, will lead to Shanghai plum precipitation increase in the rainy season, and for bands, this reflects the subtropical high peripheral strong latitude wind, especially the north side of the westerly strengthening, more prone to low jet, and Shanghai is located in the left side of the low jet, for rising movement area, when the low warm wet air is lifted to saturation, precipitation. On the contrary, if Shanghai is controlled by the subtropical high and the west wind weakens, the high temperature and fine weather will be dominated. In the east China sea near 35 °N easterly component enhancement, high latitude westerly component, and Shanghai precipitation in July and August also has a weak positive correlation, the subtropical ridge across Shanghai, Shanghai north of the subtropical high control, and north China is located in the subtropical high periphery, the circulation situation is more conducive to Shanghai precipitation, but not plum rain precipitation, and less opportunities. Therefore, the latittonal wind condition most conducive to the precipitation in the plum rainy season in Shanghai is that Shanghai is located in the north of the subtropical high, and the westerly wind jet is strengthened. The reason for the increase in precipitation in Shanghai in July and August is not only the plum rain precipitation, but also some interference under the extreme circulation situation.

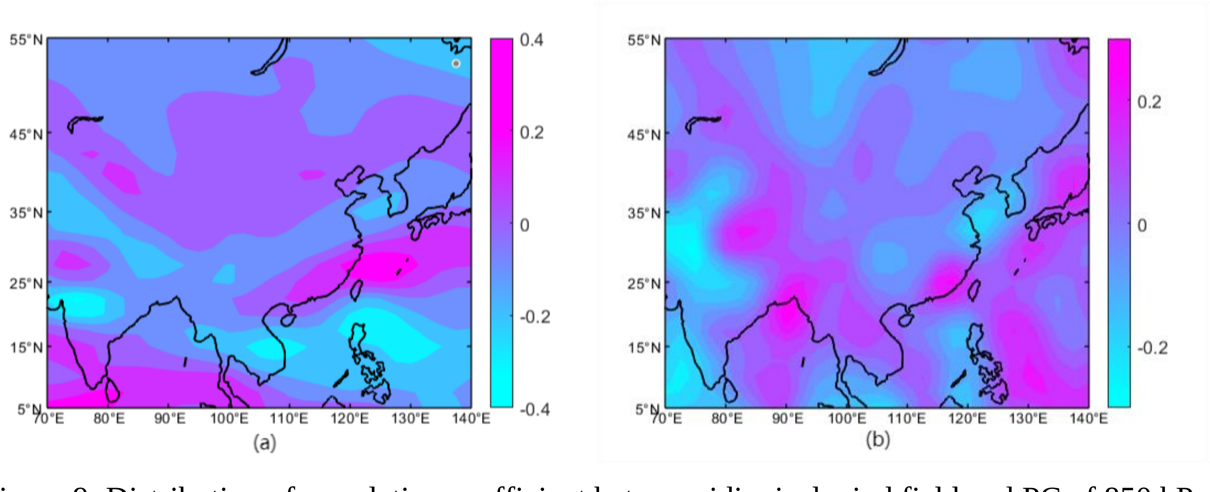

Figure 9: Distribution of correlation coefficient between idiogical wind field and PC of 850 hPa

Analysis of 850 hPa by the wind field and PC correlation coefficient distribution (figure 9a), by the wind is the most important factor conveying warm wet air, this figure clearly reflected, Shanghai southwest 25 °N near south China southerly component increase, and the Shanghai plum rainy season precipitation increased positive correlation, here the strengthening of the south wind for Shanghai continuous supply unstable energy high warm wet air, provide conditions for plum rainy season continuous rain. The increase of northerly wind in the coastal areas near 35 °N north of Shanghai also increases the precipitation in Shanghai. The dry cold air at high latitude travels to the south and meets the warm and wet air mass in the south, providing the triggering condition of precipitation, and also plays an important role in the precipitation in the plum rainy season. The range of north-south transmission is small compared with the range of east-west circulation. Different from latitudinal wind which relies on large-scale circulation, local merional wind transmission can have a direct impact on the precipitation in the plum rainy season. It can also be seen that the influence of the Indian Ocean region on the plum rain is mainly enhanced through the wind. The south wind and the north wind and the warm air of the north and south meet in Shanghai, directly increasing the precipitation of the plum rainy season in Shanghai.

6. Conclusion

Based on the detailed data, analyzes the time and space distribution characteristics of Shanghai plum rainy season precipitation, and the climate characteristics of Shanghai plum rainy season precipitation, and the EOF first mode PC, and 500 hPa, 850 hPa height field, 850 than wet field, wind field, and analyzed the characteristics of the change of climate physical quantity field changes. The main conclusions are:

(1) The time change trend of Shanghai's annual precipitation and the cumulative precipitation in the plum rainy season are similar, with inter-annual changes and inter-age changes. The interperiod precipitation showed an obvious upward trend. From the perspective of the annual precipitation, the annual precipitation of Shanghai and the cumulative precipitation of the rainy season occurred around 2000. The interannual change is the most obvious and the 2-8 year cycle shock exists, and the interchronological change is between 10-12 years.

(2) The first two modes of natural orthogonal expansion of the average precipitation in Shanghai are different from each other, which represent different climatic characteristics of the spatial distribution of the average precipitation during the Meiyu period in Shanghai. It also shows that the regional distribution of the average precipitation in the Meiyu period in Shanghai is complex and variable, but at the same time, it presents a common characteristic. The regional distribution of the average precipitation in the Meiyu period in Shanghai shows a trend of differences between the west, north and south. This shows that the average precipitation in the Meiyu period is different in the south and north of Shanghai.

(3) The maximum daily cumulative precipitation in the plum rainy season, the precipitation days in the plum rainy season, the maximum cumulative rainfall for five consecutive days in the plum rainy season and the longest continuous rainfall days in a single station all have the trend of age and years. From the perspective of age changes, the overall trend is rising except for some periods. From the perspective of inter-annual changes, there is mainly a 2-8-year cycle shock.

(4) The subtropical high in south China and the middle and lower reaches of the Yangtze river, Shanghai is located in the subtropical high periphery, plum rain rain belt affect Shanghai time extension, lead to plum rain precipitation increase, and high latitude low pressure system active, will send cold air, south and the south warm wet air interchange, also can lead to the plum rainy season precipitation in Shanghai area. The two systems with the highest correlation between the 850 hPa altitude field and the precipitation in the plum rainy season in Shanghai are the deep subtropical high and the strong Indian depression, while the middle and high latitudes have little influence on them. The peak year of Meiyu in Shanghai corresponds to the year of higher humidity in southeast coastal areas and the year of lower humidity in inland. The main source of water vapor of precipitation in plum rainy season in Shanghai is the transportation of water vapor from the Yangtze River to southeast and southwest. The high relative humidity in low latitude coastal areas and the low relative humidity in inland areas correspond to the years with more precipitation in the rainy season in Shanghai, and the increase of relative humidity in the Jianghuai River basin north of

Shanghai has the greatest impact on the precipitation in Shanghai. The lational wind condition most conducive to the precipitation in the rainy season in Shanghai is that Shanghai is located in the periphery of the subtropical high, and the westerly wind jet is strengthened. The reason for the increase of precipitation in Shanghai in July and August is not only the plum rain precipitation, but also some interference under the extreme circulation situation. The south wind and the north wind and the warm air of the north and south meet in Shanghai, directly increasing the precipitation of the plum rainy season in Shanghai.

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