Characteristics of Temperature and Precipitation Changes in Wumeng Mountain Natural Reserve in 57 Years

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Abstract: Wumeng Mountain Nature Reserve is a typical region with important characteristics such as national nature reserve, old revolutionary area and the important combination of natural geographical area, and it is a vulnerable and special area under the background of global warming. Based on the annual and monthly mean temperature and precipitation data of two meteorological stations in the protected area from 1959 to 2015, using linear tendency estimation, Mann-Kendall mutation test and Morlet wavelet analysis, the characteristics of temperature and precipitation change in Wumeng Mountain Nature Reserve were studied. The results show that since 1959, the temperature in Wumeng Mountain Nature Reserve has been decreasing, while the precipitation responsibility has been increasing, with the rates of -0.124 C/10a and 15.02mm/10a, respectively. The temperature and precipitation in the nature reserve have changed abruptly, and the temperature change is more obvious than precipitation. The periodicity of the temperature and precipitation change in the nature reserve is the most significant in the medium-long time scale and the inter annual change cycle, both 14a. The possible impact of temperature and precipitation changes on the nature reserve is briefly described, which provides a reference for rational planning and construction of the nature reserve, agricultural production and soil and water conservation in the area.

1. Introduction
Since the 1980s, climate change has become a hot issue of global concern. Many meteorological scientists have done a lot of research on the characteristics of modern climate change [1]. China has a large population, complex climatic conditions and fragile ecological environment. Climate change will have a serious impact on China. In the past 40 years, the annual average temperature in China has increased at the rate of 0.04 C/10a, and the annual precipitation has decreased at the rate of -12.66 mm/10a [2]. In the past 50 years, China's climate has been warming significantly. The annual average surface temperature increase ranges from 0.6 to 0.8 C, which is slightly higher than the global temperature rise in the same period. The precipitation has been increasing since 1956, but the increase is relatively small [3,4]. The IPCC Fifth Assessment Report points out that if people no longer pay attention to climate change, it will cause serious, universal and irreversible impacts on human and ecosystems [5,6].

Wumeng Mountain Nature Reserve, located in Zhaotong City, Yunnan Province, is an important junction of China's physical geography. The eastern part of Wumeng Mountain Nature Reserve is connected with Guizhou karst mountain plain. It faces the Sichuan Basin in the north, transits to the
central Yunnan Plateau in the South and the Hengduan Mountains in the west. It is the main channel through which cold air enters Yunnan from Sichuan Basin. In addition, it is affected by the quasi-static front of Kunming all the year round. There are many cloudy and rainy days in the reserve. Its climate characteristics are different from most of Yunnan's climate. The nature reserve is rich in biological resources, including 87 species of protected species at the national level and 19 species of protected species at the provincial level. It belongs to the special and vulnerable areas of climate change. The changes of temperature and precipitation will not only affect the organisms in the reserve, but also induce geological disasters. In addition, no previous studies have been done on the temperature and precipitation changes in this area, so to explore the temperature and precipitation changes in the protected area can not only make up for the shortcomings of temperature and precipitation changes in this area, but also provide some reference for the rational construction of the protected area, ecological restoration, agricultural production and soil and water conservation.

2. Data sources and research methods

2.1 Sources
Statistical data of monthly mean temperature and precipitation for the years 1959-2015 at the Daguan Meteorological Station (27 degrees 45'N, 103 degrees 54'E, elevation 1176.2m) and Yiliang Meteorological Station (27 degrees 38'N, 104 degrees 03'E, elevation 880.4m) were not moved, and the data series was continuous and complete.

2.2 Research methods
According to climatic statistics, spring (March-May), summer (June-August), autumn (September-November), winter (December-February), rainy season (May-October), dry season (November-April). The main research methods are linear trend analysis, non-parametric Mann-Kendall mutation test and Morlet wavelet analysis.

3. Results and analysis

3.1 Linear Trend
Under the background of global warming, the climatic factors of Wumeng Mountain Nature Reserve have changed accordingly. The annual average temperature of the reserve is 14.9 C in 57 years. The highest annual average temperature is 16.2 C in 1963, and the lowest annual temperature is 13.5 C in 1996. Since the end of 1950s, the temperature of the reserve has been declining (Fig. 1A). The rate is -0.124 C/10a, which is different from the national average. In terms of seasonal variation, except in autumn, the reserve is in a cooling state during the rest of the period, but the range is relatively small (sketch). The average temperatures in spring, summer, autumn, winter, rain and dry season were 15.4 C, 22.6 C, 15.2 C, 6.2 C, 20.3 C and 9.4 C, respectively. The rates were -0.116 C/10a, -0.135 C/10a and 0.04 C/10a, respectively. As for precipitation, the maximum precipitation in the past 57 years was 2321.2 mm in 2000, and the minimum was 1580.3 mm in 2011. There has been a slight increase since 1959 (Fig. 1B), with a rate of 15.02 mm/10a. In terms of seasonal precipitation, the seasonal distribution of precipitation in the reserve is summer > autumn > spring > winter. The average precipitation is 538.7 mm, 193.9 mm, 136.2 mm, 21.4 mm, 793.7 mm in rainy season and 97.0 mm in dry season. The precipitation in each season of the reserve showed an increasing trend, but the increase was small. The rates of spring, summer, autumn, winter, rain and dry season were 4.99mm/10a, 2.97mm/10a, 1.27mm/10a, 1.023mm/10a, 6.968mm/10a, 3.304mm/10a respectively.
3.2 Mutation Analysis

When Mann-Kendall non-parametric test is used for catastrophe analysis, when the curve of statistics UF and UB exceeds the confidence space of positive and negative 0.05, it indicates that the original sequence has a significant upward and downward trend. If the intersection of UF and UB exists in the confidence space, it means that the original sequence has a mutation, and the intersection is a mutation point. In Figure 2, the real broken line is UF curve, the virtual broken line is UB curve, and the two virtual straight lines are 0.05 confidence line [8].

From the UF curve in Figure 2A, it can be seen that the temperature of the protected area changed in three stages from the end of 1950s to 2015. The temperature of the protected area increased from the end of 1950s to the beginning of 1970s, and decreased from 1974 to 1988. Since the 1990s, the trend has been fluctuating and declining, and the trend has exceeded the confidence level of 0.05, indicating that the temperature of the protected area has been declining significantly in this stage, with 1974 as a sudden change point. From the perspective of seasonal variation (sketch), the temperature in spring before 1970s fluctuated upward stage, in late 1960s and early 1970s the temperature in nature reserve fluctuated abruptly, and in 1974-2015 it fluctuated downward trend. The downward trend from the end of 1980s to 2005 exceeded the 0.05 confidence level, and the change trend was obvious; the summer temperature showed a downward trend, in which the temperature in 1995-2015 exceeded 0.05. Confidence degree space, cooling trend is obvious, 1998 is a sudden change point; autumn temperature basically shows a fluctuating downward trend, but the range is small, after 2008 the temperature increased slightly, with a very small downward trend. The downward trend from 1987 to 2015 exceeded the 0.05 confidence line, indicating that the downward trend changed significantly during this period, with 1979 as the mutation point. The results of the dry season mutation test were basically similar to those in winter.

From the UF curve in Figure 2B, it can be seen that the precipitation in the reserve has changed in three stages over the past 57 years. From the end of 1950s to 1986, the precipitation in the reserve has basically fluctuated and increased. Especially in the 1960s, there have been two sudden changes. From 1986 to 1999, the precipitation in 1999 to 2015 shows a downward trend. The annual precipitation UF and UB curves in the reserve are basically within the confidence interval of 0.05. It shows that the precipitation in this reserve has changed slightly over the past 57 years, but it has changed greatly between years. From the perspective of seasonal variation (sketch), spring precipitation showed a fluctuating downward trend from 1959 to 1964, an upward trend from 1964 to 1986, and a lower trend from 1986 to 1999, but the range was small. It showed an upward trend from 1999 to 2015. 1998 was a sudden change point. The trend of spring precipitation did not exceed the confidence space of 0.05, indicating that spring precipitation in the reserve did not change significantly except 1967-197 in
summer. The rest of the five years showed an upward trend, with 1966, 1971 and 1972 as the breaking points, but the UF and UB curves were within the confidence interval of 0.05, indicating no obvious change; the breaking point of precipitation in autumn was large and the fluctuation was large, but the UF and UB curves were within the confidence interval of 0.05, so the trend of precipitation increase and decrease was not obvious, but the inter-annual variation was large in winter 1960s. In the 21st century, the precipitation in protected areas showed a downward trend. From the beginning of the 21st century, the precipitation in protected areas showed an upward trend, with 1979, 1985 and 2008 as the mutation points. Before the mid-1970s, the precipitation in rainy season showed an upward trend. From the mid-1970s to 2015, the precipitation in protected areas showed a downward trend. The mutation points were 1964 and 1968, but the UF and UB curves were within the confidence interval of 0.05. The trend of precipitation increase and decrease is not obvious; the precipitation in the dry season of the reserve basically shows an upward trend, and the mutation point mainly appears in the early 1970s to the early 1990s. Although the precipitation in the dry season of the reserve has been in an upward trend for 57 years, the upward trend is not obvious, but the annual fluctuation is obvious.

3.3 Evolution Period

The results show that the trend of the real part of the wavelet coefficients in time series analysis using Morlet wavelet is basically consistent with the fluctuation of the signal to be analyzed [9]. The contours are high and low value centers respectively, and the magnitude of the center value can reflect the intensity of fluctuation. From (fig. 3A), it can be seen that the annual average temperature in the protected area is 57 a time scale, with 4 low temperature centers and 3 high temperature centers in 8-9 years time scale, with 3 high temperature centers and 2 low temperature centers in 11 years scale, with 3 high temperature centers and 4 low temperature centers in 14 years scale. The cyclical changes of the core are obvious in the 14-year scale. The three high temperature centers are 1973, 1987 and 2001, and the four low temperature centers are 1969, 1983, 1997 and 2011. The results of wavelet variance show that there are 11 and 14 years oscillation periods in the annual mean temperature, of which 14 years are the main period and 11 years are the secondary period.

From Figure 3B, it can be seen that the annual precipitation in the reserve is on the time scale of 57a, with five rainy centers and one rainy center on the time scale of 8-9 years; with three rainy centers and two rainless centers on the time scale of 11 years; with two rainy centers and three rainless centers on the time scale of 14 years; among them, the cyclical variation of 14 years scale is obvious, with two high temperature rainy centers in 1973 and 1987, respectively. In 1982, 1996 and 2010, respectively. The results of wavelet variance show that there are 8, 9, 11 and 14 years oscillation periods in the annual mean temperature, of which 14 years are the main period and 11 years are the secondary period.
3.4 Discussion

Since the 1980s, climate change has become a hot issue of global concern. Many meteorological scientists have done a lot of research on the characteristics of modern climate change [1]. Most scholars have studied climate change in Yunnan on a large spatial scale, but for Yunnan, the climate of Yunnan has the characteristics of low latitude climate, monsoon climate and mountain plain climate. Under the background of global warming, the change trend of temperature and precipitation is basically the same as that of the global, Northern Hemisphere and China. However, due to the special geographical environment and location, regional differences are also significant [10,11]. The scope of this study is the variation characteristics of temperature and precipitation in Wumeng Mountain Nature Reserve. Studying this area can not only explain the characteristics of climate change in a small area, but also provide climatic basis for the construction, planning and agricultural production of Wumeng Mountain National Nature Reserve.

Since the 1990s, with increasing attention to climate change and extensive attention to biodiversity conservation, it has been recognized that climate fluctuations will have a great impact on land vegetation, herbivores and carnivores [12,13]. Studies have shown that species genetic diversity, phenology and migration have been observed due to changes in temperature and precipitation, such as northerly migration of birds, mammals and butterflies [14-17]. In the past 57 years, the temperature of the reserve has been declining, the rate is - 0.124 °C/10a, and the precipitation has been increasing, the rate is 15.02mm/10a. IPCC analysis shows that if the surface temperature rises by 3-3.5 °C, the climate zone will migrate to high latitudes by 1 and to high altitudes by 100 m [18]. On the contrary, lower temperatures in protected areas will lead to the distribution of plants to low altitude areas. The growth and decline of wild plants and crops in protected areas will also change with the changes of temperature and precipitation. The migration, initial, final and winter songs of wildlife and birds will also change, and some species will die or develop because they can not stand the changes of climate. Variations, such as strong cooling in 2008 and snow and ice weather, resulted in serious losses of natural bamboo forests in the reserve [19]. Harmful species tend to be more adaptable to the environment, and they are in a favorable position to adapt to the intense changes in the environment. As a result, lower temperatures in protected areas will make it easier for them to invade various ecosystems, thus changing the type and structure of the original system [20]. The sunshine is the primary condition for the survival of plants and animals. What's more, if the drainage is not smooth in some areas of the reserve, it will have a greater impact on plant roots and some heliophilous species.

Temperature and precipitation changes not only affect organisms, but also induce some geological disasters. Faults and folds are the most developed structures in the reserve, including Yanjin-Yongshan-Qiaojia fault, Daguan-Zhaotong-Qiaojia fault and Yiliang-Zhaotong-Qiaojia fault. And karst landform is developed. In some areas, rocks are broken under the combined action of karst and fault zones. If the precipitation increases and the intensity is high, landslides, debris flows,
collapses and other geological hazards will occur.

From the point of view of response measures, (1) Reserve Authority should adopt the strategy of germplasm gene preservation for some endangered species. (2) Because of the change of temperature and precipitation, some species can no longer adapt in the reserve, but migrate to other places. At this time, the reserve should expand the scope of protection, so that species can be fully protected. (3) Strictly monitor the changes of species in protected areas and establish relevant countermeasures. (4) Establishing disaster prevention system, in terms of the impact of climate on biodiversity, which should pay more attention to the prevention of severe rainfall, low temperature, flood and other disastrous weather, and also consider the hazards of biological invasion. (5) Preventing human destruction and adopting risk management methods to adapt ecosystems to climate change. (6) Make rational use of the periodic changes of temperature and precipitation, and formulate scientific and effective countermeasures.

4. Conclusions
(1) According to the linear trend, the temperature of the reserve has been decreasing in the past 57 years, with the annual average temperature decreasing rate of -0.124 C/10 a, and the temperature decreasing trend in every season except autumn; the precipitation shows an increasing trend, the annual precipitation increasing rate is 15.02 mm/10 a, and the precipitation in each season also shows an increasing trend; however, both the temperature and precipitation change rate are small. However, the annual variations are large. From the point of view of temperature and precipitation changes in the reserve, although in the context of global warming, there are also large regional differences.

(2) From the point of view of catastrophe analysis, the temperature of the reserve has changed in three stages in the past 57 years, rising before the 1970s, declining from the 1970s to the 1990s, and declining obviously after the 1990s, while the catastrophe point is basically in the 1970s, and the precipitation has also changed in three stages, and the precipitation has basically increased before the 1980s. From 1980s to the end of 1990s, the precipitation showed a downward trend, and after entering the 20th century, the precipitation showed an increasing trend. However, the precipitation change trend in the protected area was small, and there was no obvious precipitation change stage.

(3) From the point of view of the evolution cycle, the temperature and precipitation of the protected area in 57 years have 11 and 14 years of inter-annual variation cycle, of which 14 years of inter-annual variation cycle is the main cycle, and 11 years of inter-annual variation cycle is the sub-cycle.

(4) From the impact of temperature and precipitation changes on the nature reserve, the change of temperature and precipitation is of great significance to the construction of the nature reserve. Temperature and precipitation changes not only affect biodiversity, genetic diversity and species diversity, phenology and animal migration in the protected area, but also induce some geological disasters. So, the changes of temperature and precipitation have an important impact on the construction of nature reserves, ecological restoration and soil and water conservation.

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