Analysis of Extreme Temperature and Drought Information of Kunming

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Abstract: As greenhouse gas concentrations rise, widespread climate change increases the frequency and occur range of extreme climate events. In order to explore the change of extreme temperature and its impact on drought in Kunming, we analysis the interannual change trend of extreme temperature index (ETIs) and standardized precipitation evapotranspiration index (SPEI) based on the meteorological series data of Kunming station from the years 1959 to 2019, and studied the correlation between them. The results show that the warm index (SU25, TN90P, TX90P and WSDI) increased significantly, while the cold index (FD0, TN10P and TX10P) decreased significantly in ETIs; the rate of warming at night is higher than that at daytime. From the years 1959 to 2019, the SPEI showed a downward trend with a rate of -0.47/ (10a). This shows that Kunming has gradually changed from humid to arid in recent decades. In the correlation analysis, the warm index was negatively correlated with SPEI, while the cold index was positively correlated with SPEI. TN10P and TN90P were correlated on monthly and seasonal time scales opposite to the annual scale. ETIs and SPEI were both negatively correlated in winter in Kunming.

1 INTRODUCTION

Under the influence of global warming, the water cycle is accelerating, leading to frequent extreme climate events. The global land area and population that are affected by extreme climate events have doubled (Lange et al., 2020). Drought in extreme events reduced crop yields, increased wildfires and desertification. To better understand the reasons for the increase in extreme climate events, extreme temperatures and droughts have been studied at different regional scales.

On the global scale, the number of cold night days decreases and the number of warm night days increases in more than 70% of the world's regions (Alexander et al., 2006). On the regional scale, extreme temperature variations in the Asia-Pacific region, northern South America, and Canada (Choi et al., 2009; Aguilar et al., 2005; Zhang et al., 2000) are essentially consistent with global changes. However, the trend of drought varies in different regions (Danandeh et al., 2020; Gao et al., 2017).

Kunming, one of the rapidly developing representative cities in China, has experienced frequent droughts and floods in recent years, which have caused great losses to agricultural production and socio-economics (He et al., 2021). Current research mainly focuses on the study of extreme climate index and drought change (Wu et al., 2019; Yang et al., 2016), but did not study the specific response between extreme climate index and drought. Therefore, the study of ETIs trends and their impact on drought will help us understanding how temperature changes affect drought, as well as have importance for disaster prevention and agricultural development.

2 DATA SOURCES AND RESEARCH METHODS

Data on daily precipitation, maximum temperature, minimum temperature, and the average temperature in Kunming from the years 1959 to 2019 were provided by the National Meteorological Science Data Center.

2.1 Quality Control

We use RClimDex software to control the quality of the data for detecting inaccurate meteorological data such as precipitation less than 0, daily minimum

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Table 1: Definition of extreme temperature indices.

Classification	Index Name	Definitions	Indices	Unit
Extreme Cold Index	Frost days	Annual count when daily minimum temperature < 0°C	FD0	d
	Cold nights	Count of days where TN < 10th percentile	TN10P	d
	Cold daytimes	Count of days where TX < 10th percentile	TX10P	d
Extreme Warmth Index	Duration of warm periods	Annual count of days with at least six consecutive days in which Tmax > 90 percentile	WSDI	d
	Summer days	Annual count when daily maximum temperature > 25°C	SU25	d
	Warm daytimes	Count of days where TX > 90th percentile	TX90P	d
	Warm nights	Count of days where TN > 90th percentile	TN90P	d

temperature higher than daily maximum temperature, and outliers more than 4 times the standard deviation. We use daily meteorological data to calculate monthly mean temperature and monthly precipitation.

2.2 Research Methodology

In this paper, we selected the key seven extreme temperature indices from the ETIs recommended by the Expert on Climate Change and Indicators (ETCCDI).

2.2.1 Extreme Temperature Index

We used RClimDex 1.0 software to calculate the ETIs, and the definitions of each index are shown in Table 1. We used the Mann-Kendall (M-K) statistical test and Sen slope to assess the magnitude and significance of changes in each ETI. Pearson correlation analysis were used to measure the correlation between ETIs and SPEI.

2.2.2 Standardised Precipitation Evapotranspiration Index

The standardized precipitation index (SPI) and SPEI used by researchers in regional drought studies have become the most important drought index (Needalcov et al., 2015). Compared with SPI, SPEI takes into account the effect of potential evapotranspiration on drought (Dukat et al., 2022). Comparative studies show that SPEI is more reasonable (Suroso et al., 2021). Therefore, in this paper, we calculate SPEI values on an annual time scale, based on monthly mean temperature and monthly total precipitation. When the SPEI value is larger, it means that the area is wetter, while the SPEI value is smaller, the area is drier. We use the linear trend method to analysis the trend of SPEI in Kunming from the years 1959 to 2019 and compare the research results with the actual situation.

3 RESULTS AND ANALYSIS

Figure 1 shows the temporal variation characteristics of ETIs.

3.1 Characteristics of Interdecadal Variation in the Extreme Temperature Index

All seven ETIs passed the 0.01 significance test. The warm index (SU25, TN90P, TX90P and WSDI) increased at rates of 1.05 d/a, 0.71 d/a, 0.49 d/a, and 0.92 d/a, respectively (Fig.1a and c). The cold index (FD0, TN10P and TX10P) decreased at rates of -0.32 d/a, -0.22 d/a,and -0.08 d/a, respectively (Fig.1b and d). This indicates that the temperature in Kunming increased significantly from the years 1959 to 2019, which is consistent with previous research results (Wu et al., 2019). TN90P increased at a higher rate than TX90P, and TN10P decreased at a higher rate than TX10P, indicating that the rising rate of temperature at night was higher than that at daytime.

3.2 Characteristics of Interannual Variation in SPEI

The interannual variation trend of SPEI in the study area is shown in Figure 2. The SPEI in Kunming showed a significant downward trend from the years

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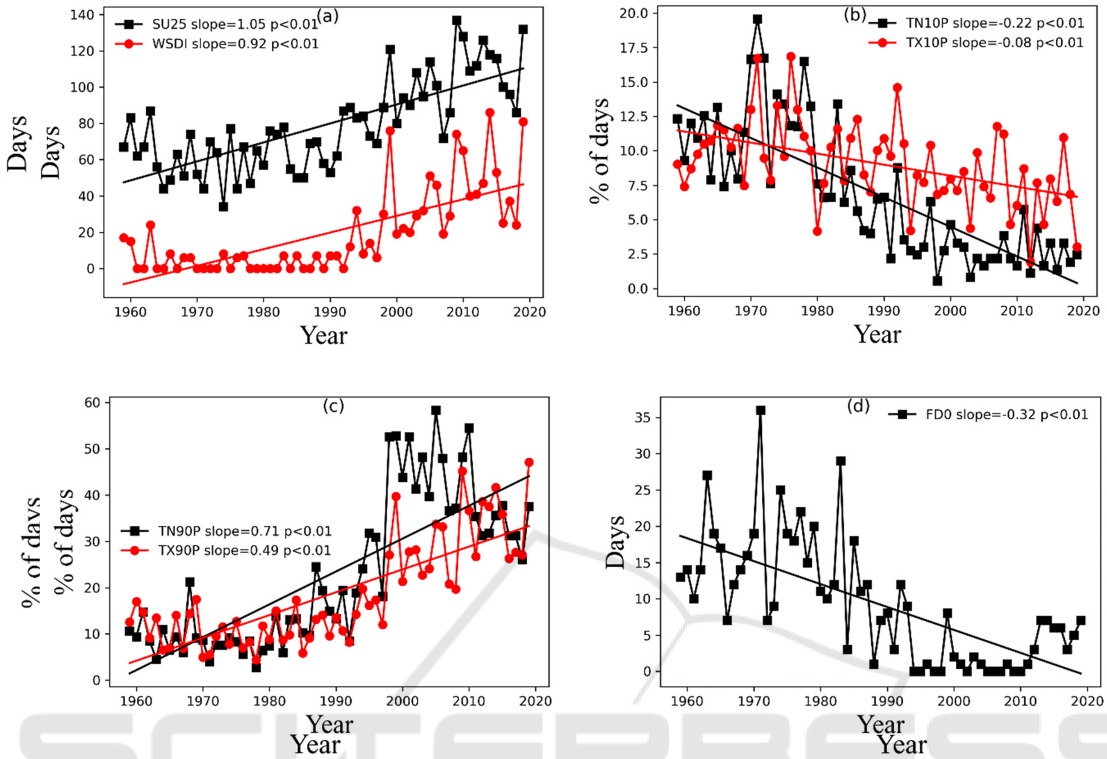

Figure 1: Changes of ETIs in Kunming from the years 1959 to 2019.

1959 to 2019, and the SPEI gradually changed from positive to negative values. It shows that Kunming has gradually changed from humid to arid in recent 80 years. The highest value (1.72) and the lowest value (-2.29) of SPEI in 1970 and 2009 respectively represent the wettest and dry years in Kunming. Tian and Wan (2016) studied the occurrence regularity of drought and flood disasters in Kunming, and the results showed that the disasters gradually changed

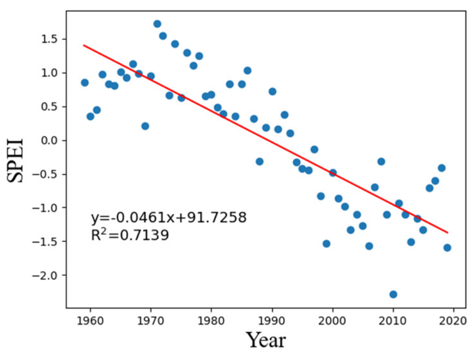

Figure 2: Trends in annual scale SPEI.

from flood to drought. In 2010, the worst drought in a century occurred in Kunming. The results of the study are consistent with previous studies and historical data.

3.3 Effects of Extreme Temperature Changes on Drought

In order to understand the impact of extreme temperature changes on drought, this paper analyzed their relationships at different time scales (monthly, quarterly and annually). Since Rclimdex only provides monthly scale data for TN10P, TN90P, TX10P and TX90P, this paper analyzed the correlation between these four ETIs and SPEI on monthly and quarterly time scales (Table 2).

At the annual scale, the extreme warm index was negatively correlated with SPEI, while the extreme cold index was positively correlated with SPEI. This indicates that Kunming is more arid when the warming index rises. As the cold index drops, it gets wetter. This may be because the precipitation in Kunming shows a decreasing trend and the precipitation tends to be more concentrated

Table 2: Correlation coefficients between ETIs and SPEI in Kunming on different time scales.

Indices (Month)	TN10P	TN90P	TX10P	TX90P
SPEI	-0.697**	0.577**	0.651**	-0.762**

Indices (Annual)	TN10P	TN90P	TX10P	TX90P	FD0	SU25	WSDI
SPEI	0.831**	-0.904**	0.676**	-0.896**	0.732**	-0.881**	-0.819**

Season	Indices	TN10P	TN90P	TX10P	TX90P
Spring	SPEI	-0.754**	0.723**	0.671**	-0.856**
Summer	SPEI	-0.776**	0.610**	0.669**	-0.870**
Autumn	SPEI	-0.872**	0.745**	0.669**	-0.797**
Winter	SPEI	-0.019	-0.033	-0.135	-0.069

Notes: ** stands for passing the significance test with p<0.01.

(Wu et al., 2020), making most of the precipitation lost due to runoff, and the temperature rise increases the surface evaporation, making the drought in Kunming more serious. However, at the monthly scale, TN10P and TN90P show the opposite correlation to the annual scale. Rising nighttime temperatures make the Kunming area wetter; falling nighttime temperatures make the Kunming area drier. At the seasonal scale, ETIs and SPEI showed significant correlations in all seasons except winter. It can be found that in winter, extreme temperature and SPEI are all negatively correlated. This phenomenon indicates that drought is most likely to occur in winter in Kunming area. The correlations between ETIs and SPEI were consistent with the monthly scale in all seasons except winter.

4 CONCLUSIONS

Among the seven ETLs, the warm index (SU25, TN90P, TX90P and WSDI) increased significantly and the cold index (FD0, TN10P and TX10P) decreased significantly. ETLs all passed the 0.01 significant test. SPEI showed a downward trend, and Kunming gradually changed from humid to arid from the years 1959 to 2019. SPEI was negatively correlated with warm index and positively correlated with cold index. On monthly and seasonal time scales (except for winter), TN10P and TN90P showed correlations opposite to the annual scale. On shorter time scales, higher nighttime temperatures made the Kunming area wetter. In winter, both extreme temperature changes made Kunming drier.

This paper briefly analysis the trends of ETIs and SPEI in Kunming and the correlation between ETIs and SPEI. However, the correlation between extreme precipitation indices and SPEI, and the specific physical factors behind the correlation between ETIs and SPEI need to be further investigated.

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