Temporal and Spatial Distribution Characteristics of Precipitation over Guangzhou, China

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Abstract. The current study probed the spatial distribution and temporal variation of precipitation extremes over the Pearl River Delta region (PRD) depended on meteorological observation data for 1960-2019. The daily precipitation for the major 7 synoptic stations in the Guangdong province of China was analyzed. It is found that the spatiotemporal heterogeneity were the distribution characteristics of PRD precipitation. In terms of spatial distribution, more precipitation value in the eastern coastal areas of Guangdong province. In general, the average annual precipitation presented an increasing trend from 1960 to 2019. At the same time, the probability and intensity of extreme precipitation with increasing tendency were analyzed in this time period. It was indicated the continuing situation of climate fluctuation that adjusted the precipitation regime of Guangzhou. Summer became the season with the largest number of statistically significant trends of extreme precipitation, mostly increasing ones.

Keywords: Extreme precipitation, temporal and spatial distribution, Guangzhou

1. Introduction
A lot of studies demonstrated that climate change and weather events are among the most critical elements for the social and economic environment. It has a profound effect on both human society and nature due to variations in the frequency and strength of some climate and weather extremes, larger than the modification in the mean value of one of the most deadly and costly natural disasters in the world [1]. Governments and academics around the world are increasingly concerned about extreme events (e.g. heavy rainfall). Numerous researchers believe that extreme events have varying trends, depending on the scales of time and space in which they occur [1-3]. In addition, a large number of simulations have suggested that increased atmospheric greenhouse gas concentrations are responsible for frequent extreme precipitation events [4-5]. Obviously, it is essential to investigate and improve understanding of future climate change projections.

The climate conditions and extreme weather events in China happened significant changes in the last century [6]. In particular, precipitation extremes during the summer monsoon season was regarded one of the most damaging climatic episodes in China. The trends in precipitation in China have been investigated by several authors [7-10]. The majority of studies concentrated on the monthly-seasonal average conditions and the summer.

Zhai et al. had reported no obvious trend in precipitation per year from 1951 to 1995, but it was considerably higher than the normal average rainfall [11]. During the period 1951-2002, Gemmer et al.
identified a negative tendency for monthly precipitation in spring and autumn in eastern China, while a positive influence was observed in summer [7]. Other research has found that from the 1950s to the mid-1970s, the average precipitation in eastern China showed a significant decreasing trend, and from the late 1970s onwards, the average precipitation showed an increasing trend [12, 13].

The Pearl River Delta region has obvious changes in rainfall of the area and is a region vulnerable to the effects of climate change. The climate change affected the terrestrial water-cycle by changing the hydrologic variables (such as precipitation), so unbalanced distribution of precipitation in the Pearl River Delta was more probably to be further driven by climate warming [8]. In addition, the extraordinarily rapid urbanized areas in recent decades, southern China, and the PRD region, in particular, extreme precipitation events have plagued the region [10]. In order to reveal the response mechanism of precipitation processes to climate change, this paper analyzes the precipitation trends in the Pearl River Delta region in four seasons, particularly the tendency of extreme precipitation events.

2. Data and Method

2.1. Study Area
Guangdong province locates between 109°39'–117°19' east longitude and 20°13'–25°31' north latitude, including the major Zhuijiang River (Pearl River) basin. It is higher in the north and lower in the south, and has the land area about 179,700 km². The north of Guangdong Province is the hills with concentrated forests, the middle is a hilly basin, and the south is a coastal alluvial plain, which is a component of the Pearl River Delta. Guangdong has a tropical and subtropical monsoon climate, characterized by high temperate and rainy in summer. The mean annual temperature is 20-22 degrees Celsius, and annual precipitation is approximately 1720 mm. The precipitation gradually reduced from the south to the north in this zone. This study focuses on the precipitation data of eight meteorological stations of Guangdong in 1960-2019.

2.2. Methods
The data were derived from the China Meteorological Administration (CMA) (http://data.cma.cn/) and focused on analyzing daily precipitation data from seven Meteorological stations from 1960 to 2019. This study adopted the annual maximum method and percentile threshold method to analyze the extreme value of precipitation in Guangzhou. These indices can reflect changes in intensity, frequency, and duration of precipitation. These precipitation indices were included maximum 1-day precipitation (RX1day), maximum 5-day precipitation (RX5day), the simple daily intensity (SDII), the heavy precipitation days (R10 mm) and very heavy precipitation days (R20 mm), consecutive dry days (CDD), consecutive wet days (CWD), precipitation on very wet (R95p) and extremely wet days (R99p) and annual total wet-day precipitation (PRCPTOT). In order to assess the spatiotemporal changes’ precipitation extremes over Guangzhou, we used different statistical approaches: Mann–Kendall, Sen’s slope estimator, and linear regression. Mann-Kendall's test method is a non-parametric method [14].

3. Results and Discussion

3.1. Spatial Distribution of Precipitation
Figure 1 displayed the regional annual average for precipitation over Guangdong during 2000-2019. The spatial distribution of the annual average precipitation has a typical regional distribution characteristic, which decreases gradually from south to north, and there is a high-value area in the coastal areas, particularly the estuary of the Pearl River. The main factors affecting precipitation are the monsoon activity to a large degree and topography (air mass uplift precipitation). The highest value of precipitation is 2463.3 mm during this period.
3.2. Temporal Variability and Trends of Precipitation
Figure 2a demonstrates the regional annual series for precipitation in Guangzhou city during 1960-2019. It was found that the annual average precipitation experienced an increasing trend of about 1.24 mm/year. It shows that the annual precipitation varied with the highest of 2526.9 mm in 2001, the lowest of 252.3 mm in 1999, and the mean of 1504 mm. The annual precipitation with the biggest value was about 10 times of the smallest value. The annual precipitation with the lowest value was 0.17 times the mean value. It was noticeable for the annual change of precipitation in this city.

It displayed that the annual precipitation fluctuates greatly and plentiful-scanty precipitation alternates frequently (see figure 2b). There were two significant cumulative anomalies of annual precipitation in 1989 and 1998. The values of abnormal rainfall were 286 mm and 289 mm, respectively. Before the 1990s, the values of rainfall in Guangzhou were lower and less than the average value of precipitation. Since 1992, the most of the average annual precipitation has been more than the mean value. The frequency and intensity of abnormal values were increased significantly after the 1990s.

3.3. Analysis of Correlations of Precipitation Indices
Figure 3 revealed the correlation of these extreme precipitation indexes. It was clear that a significant correlation between PRCPTOT and other extreme precipitation indices. It suggested that the rainfall in Guangzhou is more from precipitation ≤10mm. The highest positive correlation coefficient was found
between R10 mm and PRCPTOT (0.943). The maximum negative correlation coefficient is between R10 mm and CDD value (-0.513). CDD and (except SDII) others indexes show a negative correlation. It indicated that the extreme precipitation events were increased dominated during 1960-2019.

Figure 3. Correlation analysis of extreme precipitation indices.

4. Conclusions
Based on the observation data of precipitation surface weather stations in Guangzhou from 1960 to 2019, the temporal and spatial distribution of precipitation is analyzed. We found that average annual precipitation during 2010-2019 has increased by 42.6mm per station compared to the average annual precipitation during 2000-2009. The average annual precipitation in Guangzhou was 1504.01mm, showing the increasing trend. Generally, the frequency and intensity of outliers increased significantly. There are the increasing trend of extreme precipitation events from 1960 to 2019.

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