A Study for Consecutive Precipitation Pattern Based on Stochastic Ordering

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A Study for Consecutive Precipitation Pattern Based on Stochastic Ordering

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Abstract: Consecutive precipitation extremes may cause more catastrophes than occasional extreme events. They may pose more serious threats to the safety of people's lives and property. They also can cause great damage to the healthy development of social economy. It is of practical significance to explore this issue. In this work, a nonparametric approach based on stochastic ordering combined with EI Barmi-McKeague test was employed, which is more flexible if the trend is non-monotonic or more complex to model. The average summer consecutive precipitation in 31 provinces of China were compared in three periods, 960-1965, 1985-1990 and 2010-2015. Based on this approach, the results showed that, in 17 out of the 31 provinces, the consecutive precipitation in summer increase stochastically from period 1 to period 2 or period 3, or increase stochastically from period 2 to period 3. These 17 provinces mainly located in Northwest and Southeast China. Given the increases in the average summer consecutive precipitation and the high single consecutive precipitation of provinces which located in the Southeast China and socio-economic vulnerability to such extremes in China, the local government and relevant national departments should adopt more strategies to alleviate and adapt to the increasing trend of consecutive precipitation extremes.

Keywords: consecutive precipitation; nonparametric tests; wet days; stochastic ordering;

1. Introduction

Under the background of global warming, the change of extreme weather and climate events has attracted extensive attention of scholars worldwide. There have been a lot of studies on extreme climate change in China. The precipitation indices include maximum 1-day precipitation, annual total wet-day precipitation, the number of heavy precipitation days and very wet days. Most of the studies are about the frequency or intensity of extreme weather events, such as the frequency of extreme wet events [8], trends of maximum 1- day precipitation, annual total wet-day precipitation, the number of heavy precipitation days and very wet days [9], the tendency of annual mean and extreme precipitation [10].

Much work on the trends of precipitation also has been conducted in different regions, and has shown that the trends in precipitation were uneven in both space and time. Gong et al. (2004)[11]studied the daily precipitation changes and found out that the precipitation amounts in the semi-arid region over northern China show slightly decreasing trends. There are almost no significant trends in annual mean and extreme precipitation in the Zhujiang River Basin[10]. The regional maximum 1-day precipitation and annual total wet-day precipitation on average, show insignificant increases in the arid area of northwestern China[9]. In Sichuan Province, the characteristics of the total summer precipitation, extreme summer precipitation days, and summer extreme precipitation intensity were inconspicuous, while the extreme precipitation in the late-21st century exhibited a certain degree of increase[12]. During the summer monsoon period, extreme wet events exhibit a slight decreasing trend with fluctuations in Southwestern China[8]. Shi et al. (2018)[1] analyzed the temporal and spatial distributions and tendencies in the consecutive temperature and precipitation extremes in China during 1961–2015, which calculated linear trends of consecutive days of precipitation extremes. Insignificant decreasing trends are also found for consecutive dry days in the arid area of northwestern China [9].

Decreasing trends in consecutive dry days were detected at most stations of Yangtze River Delta[13].

Consecutive dry days and consecutive wet days are the two indices most frequently involved in the studies for consecutive precipitation. Previous studies on extreme weather and climate events have suggested that consecutive temperature or precipitation extremes may cause more catastrophes than occasional extreme events, and will pose more serious threats to the safety of people's lives and property and the healthy development of social economy[6,7]. Here, we focus on the consecutive precipitation in summer over China in this work. We would like to provide references for the scientific research on consecutive precipitation change and to improve the risk prevention ability of regional disastrous weathers.

The outline of the current article is as follows. In Section 2, we introduce the sources where the data comes from, the average consecutive precipitation, stochastic ordering of random variables and empirical likelihood-based test for stochastic ordering. In Section 3, based on the stochastic ordering and nonparametric test we compared the average summer consecutive precipitation in 31 provinces of China in three periods, 960-1965, 1985-1990 and 2010-2015. Finally, the discussion is presented in Section 4.

2. Data and Methods

2.1. Study data

The observed daily total precipitation data covering 1960–2015 from 756 national key meteorological stations were provided by the National Meteorological Information Center, China Meteorological Administration. Based on a combination of criteria involved in the spatial distribution of meteorological stations and the length, completeness and quality of data series, data actually used in this study was further selected. Potential errors or outliers are taken care of in the validation process. Preliminary quality controls were implemented to check the data gaps for all series. Finally, among all 756 stations, 569 stations with a time span from 1960 to 2015 which have complete precipitation data were reserved. The location of the weather stations is shown in Fig. 1. Stations were uniformly distributed, with more stations in the central, eastern and southern parts of China, while less stations in some areas of the western and northeastern China.

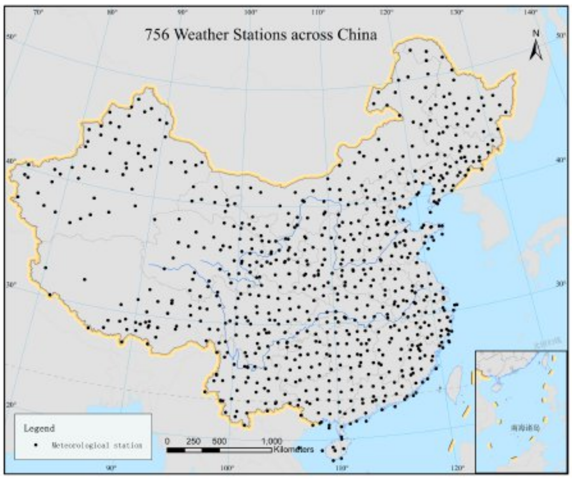

Figure 1. Spatial distribution of selected meteorological stations

2.2. Consecutive Precipitation

Wet days were defined as the precipitation less than 1 mm/day in many articles [1,2]. The threshold also can be lowered in areas with relatively low precipitation. As considering the vast regional differences in China, a threshold of 0.1mm/day was used in [3]. Since 31 provinces (municipalities or autonomous regions) are involved in our research, we choose the latter threshold, that is 0.1mm/day. There are many researches on the consecutive wet days[4,5], but few researches involve the consecutive precipitation. Here, a consecutive precipitation refers to the total amount of rainfall in the single consecutive wet days. For example, the rainfall in some place starts on June 1 and ends on June 4, then the single consecutive precipitation here is the total amount of rainfall from June 1 to June 4. Since in China, the summer rainfall in most areas is the highest in the whole year, we only focus on the summer season (June to August) here. We take the average value of the single summer consecutive precipitation over all stations in each province, and explore their changes in three periods.

2.3. Stochastic Ordering and Nonparametric Test

2.3.1. Stochastic Ordering of Random Variables

There have been many methodologies to study the spatial and temporal characteristics of consecutive precipitation. The nonparametric Mann-Kendall (MK) test [13,14,15,1,16,17,18] and linear regression model[19,20,21] are the two most primary statistical procedures to detect a possible trend. The Mann-Kendall test makes no assumption about the probability distribution of a time series and it can be used to test whether a time series has a monotonic trend. The linear regression model often makes the implicit assumption of normal distribution. In this article, we intend to explore the characteristics of consecutive precipitation for 31 provinces in China. We take Neimenggu province for an example, Figure 2 shows the average consecutive precipitation of summer in Neimenggu province from 1960 to 2015.

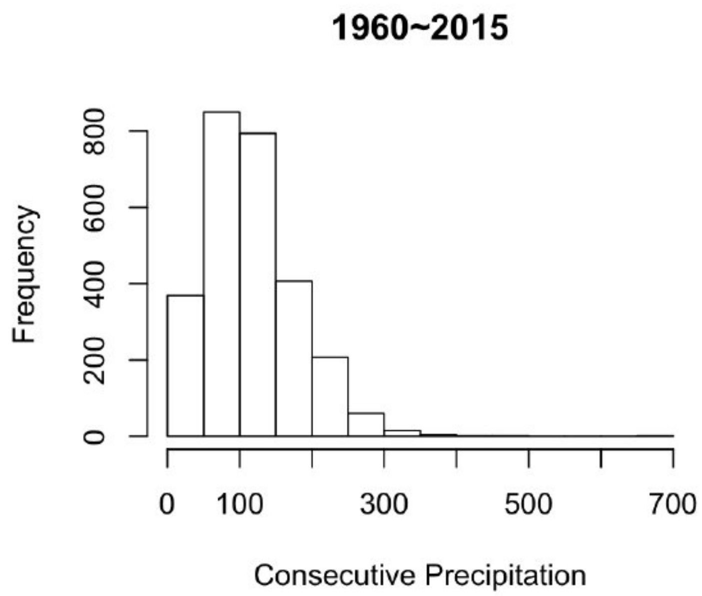

Figure 2. Histograms for consecutive precipitation of summer month from 1960 to 2010 in Neimenggu province.

Obviously, the data are very skewed and have a heavy tail. Hence, linear regression model is not a good choice for us. Although the Mann-Kendall (MK) test makes no assumption about the probability distribution, it is only suitable to examine whether a time series has monotonic trend. In the current article, we intend to explore the characteristics of summer consecutive precipitation in 31 provinces, however, it doesn't show any obvious trend or change over time in some provinces. We take Neimenggu as an example, as shown on Figure 3. There is no obvious trend for the average summer consecutive precipitation over the whole period from 1960 to 2015. We also plot the histograms for average consecutive precipitation of summer months in 1960-1965 and 2010-2015 in Neimenggu province in Figure 4.

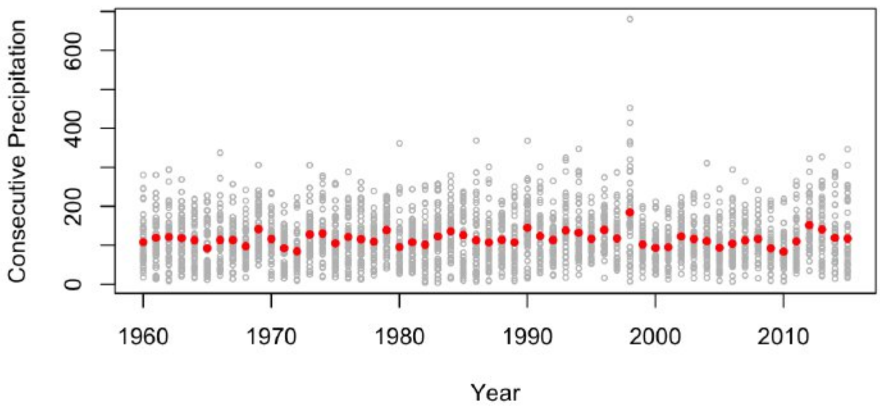

Figure 3. Time series of the summer consecutive precipitation (in 0.1mm) at each station (gray circle) and their average over all stations (solid red) in Neimenggu Province from 1960 to 2015.

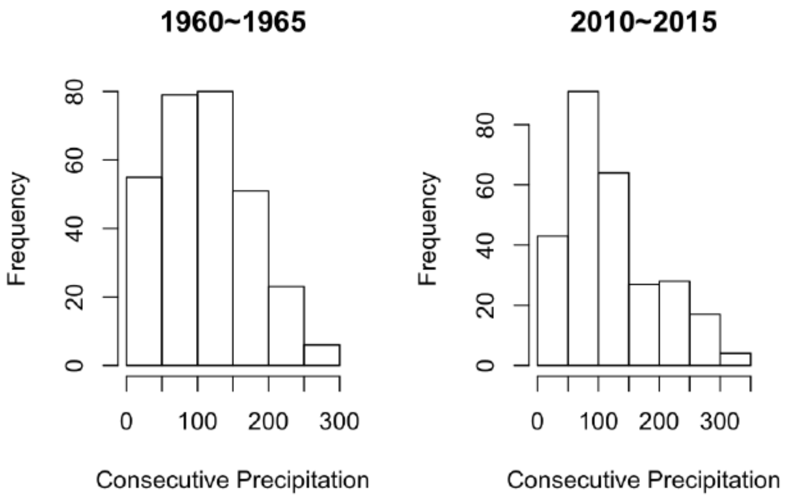

Figure 4. Histograms for consecutive precipitation of summer months in 1960-1965 (left) and 2010-2015 (right) in Neimenggu province

While the histograms in Figure 4 seem to suggest that the summer consecutive precipitation during 2010-2015 are “larger” than those during 1960-1965, and the summer consecutive precipitation in both periods are skewed. The change over time can be translated into stochastic ordering, a probability concept to sort random variables in an increasing or decreasing order. Stochastic ordering is a powerful statistical procedure and would be helpful that could detect changes, which has a higher power than the existing test procedure. The idea of stochastic ordering is first proposed by Moshe Shaked and George Shanthikumar[22], and this statistical method has been used in survival analysis [23] and operations research [24]. From a statistical point of view, if the cumulative distribution function of a random variable is less than or equal to that of another variable, then the random variable is called as stochastically larger than another random variable. For example, the empirical cumulative distribution function of summer consecutive precipitation in two time periods, 1960-1965 (red line) and 2010-2015 (green line) in Neimenggu Province is shown on Figure 5 below. We can see that the cdf for summer consecutive precipitation in 2010-2015 is lower than that in 1960-1965, which means that from 1960-1965 to 2010-2015, the summer consecutive precipitation is increasing.

Surely, this need a formal statistical test to verify it，which will be introduced in the following section. In the current article, we pick three periods of time, 1960-1965, 1985-1990, and 2010-2015, and take the summer consecutive precipitation as the random variables. Based on this statistical method Stochastic Ordering, we do a pairwise comparison in these three periods.

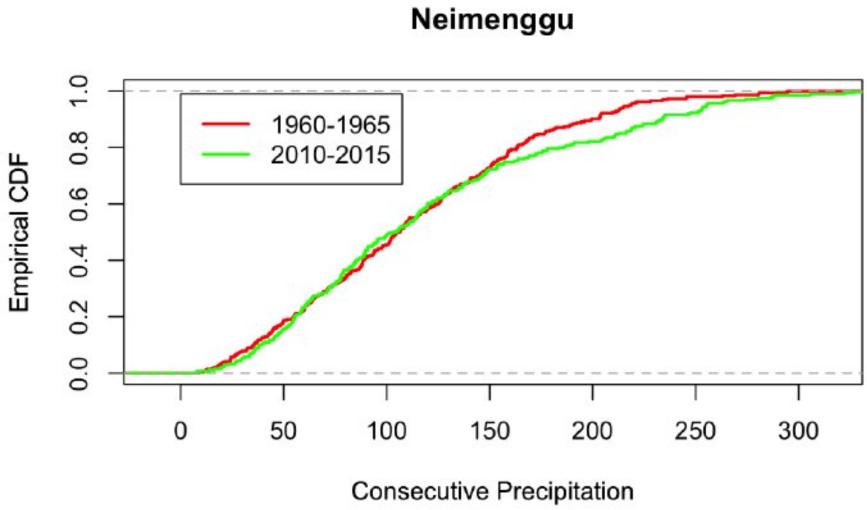

Figure 5. The empirical cdfs of ACDD in two time periods, 1960-1965 (red line) and 2010-2015 (green line) in Neimenggu Province.

2.3.2. Empirical Likelihood-Based Test for Stochastic Ordering

We are so lucky that we have resource for reference. Nan Ni and Hao Zhang made a research on precipitation pattern through Stochastic Ordering, where the summer consecutive dry days in three periods of time, 1960-1965, 1985-1990 and 2010-2015 are compared[24]. This is the first time that this research method has been applied to the study of extreme climate events. In their study, they employ this formal statistical test based on empirical likelihood which is developed by EI Barmi and McKeague[25]. This test has been shown to be more powerful than other test procedures. This current article is to do their follow-up research with this method. What follows is a brief summary of this test.

Given two random variables X_1 and X_2, with cumulative continuous distribution functions F_1 and F_2, if $P\ (X_1 > x) \geqslant P\ (X_2 > x)$ for all x, or equivalently, $F_1(x) \leqslant F_2(x)$ for all x, then the ordering is denoted by $X_1 \succ X_2$ or $F_1 \succ F_2$. The main work to be done next is to test the hypothesis

$$\boldsymbol{H_0}: \boldsymbol{F_1} = \boldsymbol{F_2}\,, \boldsymbol{against} \quad \boldsymbol{H_1}: \boldsymbol{F_1} \succ \boldsymbol{F_2} \tag{1}$$

Suppose there are two random independent samples, whose sizes are $\boldsymbol{n_j}$ and cumulative continuous distribution functions are $\boldsymbol{F_j}\ (\boldsymbol{j} = \mathbf{1}, \mathbf{2})$. The empirical cdf of the jth sample is denoted by $\widehat{\boldsymbol{F_j}}$, and the cdf of the pooled sample is denoted by $\widehat{\boldsymbol{F}}$. Let $\left(\widetilde{\boldsymbol{F_1}}(\boldsymbol{x}), \widetilde{\boldsymbol{F_2}}(\boldsymbol{x})\right)$ be the weighted least squares projection of $(\widehat{\boldsymbol{F_1}}(\boldsymbol{x}), \widehat{\boldsymbol{F_2}}(\boldsymbol{x}))$ onto the set $\{(\boldsymbol{z_1}, \boldsymbol{z_2}): \boldsymbol{z_1} \leq \boldsymbol{z_2}\}$, with weights $\boldsymbol{\omega_j} = \boldsymbol{n_j}/\boldsymbol{n}$, where $\boldsymbol{n} = \boldsymbol{n_1} + \boldsymbol{n_2}$[26]. Among all $0 \leq \boldsymbol{z_1} \leq \boldsymbol{z_2} \leq \mathbf{1}$, by minimizing the projection

$$\sum_{\boldsymbol{j}=\mathbf{1}}^{\mathbf{2}} \boldsymbol{w_j} \left(\widehat{\boldsymbol{F_j}}(\boldsymbol{x}) - \boldsymbol{z_j}\right)^{\mathbf{2}}$$

We will have the solution

$$\begin{cases} \widetilde{F_j}(x) = \widehat{F}_j(x), j = 1,2 \;\; if\; \widehat{F}_1(x) \le \widehat{F}_2(x) \\ \widetilde{F_1}(x) = \widetilde{F_2}(x) = \sum_{j=1}^{2} w_j \widehat{F_j}(x) \;\; if\; \widehat{F}_1(x) > \widehat{F}_2(x) \end{cases}.$$

Denote

$$\mathcal{R}(x) = \prod_{j=1}^{2} \left[\frac{\widehat{F}(x)}{\widetilde{F_j}(x)}\right]^{n_j \widehat{F}_j(x)} \left[\frac{1-\widehat{F}(x)}{1-\widetilde{F_j}(x)}\right]^{n_j(1-\widehat{F}_j(x))}$$

where any term raised to the zero power is set to 1. Then the test statistics is given by

$$T_n = -2\int_{-\infty}^{\infty} log\ \mathcal{R}(x) d\widehat{F}(x)$$

Obviously, $\widehat{F}(x)$ is a step function, the integral above can be expressed as a finite sum. Then,

$$p_i = \widehat{F}(x_i) - \lim_{x \to x_i^-} \widehat{F}(x)$$

Where $x_i, i = 1, 2, \ldots, m$ is the unique values in the pooled sample and p_i is the step jump at x_i. Therefore, the test statistics can be written as following,

$$T_n = -2\sum_{i=1}^{m} p_i log \mathcal{R}(x_i)$$

EI Barmi and McKeague (2013) showed that T_n has the limiting distribution below(see Theorem 2 and Remark 2 in [25]) .

$$T_n \xrightarrow{d} \int_0^1 \frac{B^2(t)}{t(t-1)} I(B(t) \ge 0) dt$$

Here B is a standard Brownian bridge. By simulations, they got the critical values 1.821 and 3.185, for the significance level $\alpha = 0.05$ and $\alpha = 0.01$ respectively. If T_n is greater than the critical value, the null hypothesis H_0 will be rejected.

2.3.3. Examples

Let's go back to Figure 3, Figure 4 and Figure 5. We take the summer consecutive precipitation in Neimenggu province as an example. As shown on Figure 3, the summer consecutive precipitation in Neimenggu doesn't have obvious trend during the whole period from 1960 to 2015. The linear regression model also gives us the same conclusion. While after taking a closer look at Figure 4, we can find the difference between the two period 1960-1965 and 2010-2015. The summer consecutive precipitation during 2010-2015 are "larger" than those during 1960-1965. Corresponding to Figure 5, We can see that the cdf for summer consecutive precipitation in 2010-2015 is lower than that in 1960-1965, which confirms the conclusion above. But this is only an observation conclusion. We need a formal statistical verification, fortunately, EI Barmi and McKeague (2013) did it for us. We take F_1 and F_2 as the cdfs of the summer consecutive precipitation of Neimenggu in 2010-2015 and 1960-1965, respectively. We want to test the alternative hypothesis $F_1 \succ F_2$, as shown in Formula (1). The value of the test statistics T_n *i*s 1.82266, which is greater than the critical value 1.821 at the significance level $\alpha = 0.05$. So the null hypothesis H_0 can be rejected. The evidence that the summer consecutive precipitation in 2010-2015 is stochastically larger than that in 1960-1965 is strong. The statistical test also confirms what be shown on Figure 4 and Figure 5.

3. Results

As a follow-up work of the study from Nan Ni and Hao Zhang[24], we choose the same three periods of time, 1960-1965, 1985-1990, and 2010-2015. The average summer consecutive precipitations of each province in China are compared in the three time periods by applying the EI Barmi-McKeague test. The symbols F_1, F_2, F_3 represent the cumulative distribution function of the summer consecutive precipitations in the three time periods above. The following three cases will be tested: $F_2 \succ F_1, F_3 \succ F_1, F_3 \succ F_2$.

The next work is divided into two steps. Step one, for the sake of illustration, we divide 31 provinces into 4 different clusters. The basis of our classification is the hierarchical clustering[27]. Provinces with similar average consecutive precipitation will fall into one cluster. After applying the Euclidean distance to measure the similarity of different provinces, we employ Ward's minimum variance method for clustering. We summarize the clustering result in Table 1. The resulting clusters is shown on Figure 6, which is plotted in a dendogram.

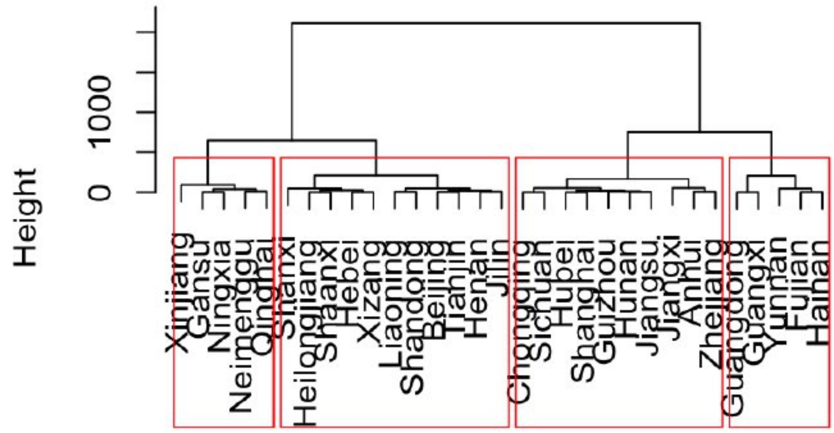

Figure 6. Dendogram of Hierarchical Clustering Analysis of Summer Consecutive Precipitation in China.

Table 1. Clustering of provinces based on average consecutive precipitations in the summer months

Cluster	Province	Average consecutive precipitation
Cluster 1	Gansu, Ningxia, Neimenggu, Qinghai, Xinjiang	45-130
Cluster 2	Beijing, Hebei, Heilongjiang, Henan, Jilin, Liaoning, Shaanxi, Shandong, Shanxi, Tianjin, Xizang	160-270
Cluster 3	Anhui, Chongqing, Guizhou, Hubei, Hunan, Jiangsu, Jiangxi, Shanghai, Sichuan, Zhejiang	310-420
Cluster 4	Fujian, Guangdong, Guangxi, Hainan, Yunnan	450-570

We note that the resulting clusters in this current article is different from the clusters in the article of Nan Ni and Hao Zhang[24], especially in cluster 3 and cluster 4. In our result, these five provinces，Fujian, Guangdong, Guangxi, Hainan, Yunnan are classified into cluster 4. While in the article of Nan Ni and Hao Zhang[24], the cluster 4 only contains two provinces, Guangdong, Guangxi. The main reason for this difference is that the basis for clustering is different. We divided the four clusters based on the average summer consecutive precipitation in this work, while their basis is the summer daily precipitation. This also shows that our research of this paper is of practical significance. Figure 7 better shows the geographical characteristics of these four clusters than Figure 10 in [24]. As we can see, the 5 provinces of Cluster 1 are mainly located in the Northwest China, the 11 provinces of Cluster 2 lies in the

North and Northeast China, the Cluster 3 which consists of 10 provinces represents the Central China, and the Cluster 4 contains Fujian, Guangdong, Guangxi, Hainan, Yunnan, are located in the southernmost part of China.

Figure 7. Spatial Locations of Clusters

Step two, the summer consecutive precipitations of each province in China are compared in the three time periods by applying the EI Barmi-McKeague test. We denote the value of the test statistics T_n in three periods as Y_1, Y_2, Y_3 respectively, which means that the value of the test statistics in 1960-1965 is denoted as Y_1, the value of the test statistics in 1985-1990 is denoted as Y_2, and the value of the test statistics in 2010-2015 is denoted as Y_3. The results of comparison by the EI Barmi-McKeague test are shown in Table 2. The values greater than 1.82266 are marked in black italics. The result of comparison is not as obvious as that of the average number of consecutive dry days (ACDD), which shown in Table 2 in [24]. But the regional characteristics are more obvious.

Table 2. Test statistics for stochastic ordering of Summer Consecutive Precipitation in each province. Bold italic values indicate values greater than the critical value at the 0.05 significance level.

Clusters	Provinces	$Y_2 > Y_1$	$Y_3 > Y_1$	$Y_3 > Y_2$
	Gansu	1.2402671	***2.6780711***	0.7690448
	Ningxia	***1.9581422***	0.6802479	0.2325673
Cluster 1	Neimenggu	0.9769551	***1.8226644***	0.7076345
	Qinghai	***2.9837645***	***6.1609059***	0.7200942
	Xinjiang	***2.925294***	***18.999123***	***7.668278***
	Beijing	***1.82726182***	0.31977177	0.05282731
	Hebei	0.32583230	0.03739536	0.02729105
	Heilongjiang	0.05231214	0.03139594	0.15750904
	Henan	0.000000	0.06699421	0.5129424
Cluster 2	Jilin	0.7642455	0.005982540	0.000000
	Liaoning	0.02228394	0.05224933	0.09608767
	Shaanxi	0.8635147	***2.6307195***	0.7838998
	Shandong	0.00000	0.00000	0.8698925
	Shanxi	***2.436337***	1.016110	0.676589

	Tianjin	0.04314564	0.08323828	0.34643858
	Xizang	0.16864433	0.19488483	0.08360956
Cluster 3	Anhui	***2.1908161***	***5.7448092***	0.6368282
	Chongqing	0.71560527	0.15455318	0.01307137
	Guizhou	0.1936387	0.2938668	0.3080896
	Hubei	0.057060887	0.028907398	0.002986117
	Hunan	***4.2023351***	***6.1679729***	0.8450239
	Jiangsu	0.002600757	1.485627037	***4.181390727***
	Jiangxi	0.08399284	***9.65043026***	***14.71594676***
	Shanghai	***1.8690586***	0.9772872	0.2270258
	Sichuan	0.06350097	0.75759468	1.34036494
	Zhejiang	***1.975828***	***22.178531***	***12.945538***
Cluster 4	Fujian	0.006734792	0.093704955	***17.081298477***
	Guangdong	0.04493528	0.04376839	***5.06764164***
	Guangxi	0.01494462	***2.00079447***	***7.69024651***
	Hainan	0.2033015	0.9681892	1.7316994
	Yunnan	0.003511056	0.00000	0.03238938

We can see that there exist significant differences among different clusters. In Cluster 1, all provinces have stochastically increasing for summer consecutive precipitation from period 1 to either period 2 or period 3, or increasing from period 2 to period 3. In Cluster 2, Only three of the 11 provinces showed an increasing stochastically trend from period 1 to either period 2 or period 3, and there is no significant difference between period 2 and 3. In Cluster 3, the summer consecutive precipitation increases stochastically from period 1 to either period 2 or period 3, or increasing from period 2 to period 3 in 6 out of 10 provinces. In Cluster 4, the three provinces Fujian, Guangdong, and Guangxi increase stochastically for summer consecutive precipitation from period 2 to period 3, only Guangxi province have increasing stochastically from period 1 to period 3. None of the five provinces show increasing stochastically from period 1 to period 2.

In total, 9 out of the 31 provinces have summer consecutive precipitation increasing stochastically from period 1 to period 2, 10 out of the 31 provinces have summer consecutive precipitation increasing stochastically from period 1 to period 3, 7 out of the 31 provinces have summer consecutive precipitation increasing stochastically from period 2 to period 3. 17 out of the 31 provinces have summer consecutive precipitation increasing stochastically from period 1 to period 2 or period 3, or increasing stochastically from period 2 to period 3. We distinguish the 17 provinces from the other 14 provinces by different colors in Figure 8, these 17 provinces are marked green, and the other 14 provinces appear yellow. Furthermore, We note that the summer consecutive precipitation have obviously region difference as shown in Figure 8. These 17 provinces are located in northern and southern China, especially in the Northwest and the Southeast. The other 14 provinces which have not any stochastically increasing are mainly located in the Central, Northeast, and Southwest China.

Figure 8. Spatial Locations of the 17 Provinces (green parts) Which Show Increasing Stochastically from Period 1 to Period 2 or Period 3, or from Period 2 to Period 3.

4. Discussion

As a follow-up work of Nan Ni and Hao Zhang[24], we explore the spatial and temporal changes in summer consecutive precipitation by using the method of stochastic ordering, and applied the EI Barmi-McKeague test for stochastic ordering. In this work, we choose the same three periods as in [24], which is 1960-1965, 1985-1990, and 2010-2015. The results show obvious regional characteristics, 17 provinces which located in the North and South, especially in the Northwest and Southeast China, show increasing stochastically from period 1 to period 2 or period 3, or from period 2 to period 3, while the other 14 provinces have no significant stochastically increasing. It is particularly noteworthy that the spatial characteristics are significant for both the average summer consecutive precipitation and the results of EI Barmi-McKeague test for stochastic ordering, as shown in Figure 7 and Figure 8 respectively. For the provinces which located in the Northwest China, such as Gansu, Ningxia, Neimenggu, Qinghai, Xinjiang, the average single consecutive precipitation is small and the average total precipitation of summer is only 5-25mm. As we can see in Table 1, the average single consecutive precipitation is 4.5-13mm for provinces in Cluster1, and water resources are scarce in these provinces. Hence the stochastically increasing should probably a good message for them. However, for the provinces which located in the Southeast China, such as Fujian, Guangdong, Guangxi, the average total precipitation of summer can be as high as 60-120mm, the average single consecutive precipitation is 45-57mm. They are rainy provinces, water resource is abundant. The increasing of summer consecutive precipitation of these provinces may cause great floods and cause great disaster to people's life and social property. Therefore the relevant departments of water resource management should pay enough attention to it.

A possible future improvement of this work is to implement EI Barmi-McKeague test for the maximum continuous precipitation distribution of China. Our current research is about the pattern of average summer consecutive precipitation, the maximum continuous precipitation is a more extreme form, which will cause more destructive effect. There exist many studies on consecutive precipitation extremes. Most of them are about the consecutive wet days and consecutive dry days. Some studies explored consecutive precipitation using the method of linear regression for the maximum consecutive 5-day precipitation totals[28], or microwave analysis for the maximum consecutive precipitation in each month[29]. The Barmi-McKeague test employed in our current article is more flexible for the model, whose trend is non-monotonic or more complex, as we can see from the results above.

Author Contributions: All the three authors contributed substantially to the manuscript. W.X.C. performed all the statistical analysis and is primarily responsible for writing the manuscript. H.Z. proposed the methodology, put forward the basic framework, and performed the revision of the manuscript. The Figure 1, Figure 7 and Figure 8 were drawn by Y.Y.X.

Conflicts of Interest: The authors declare no conflict of interest.

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Figures

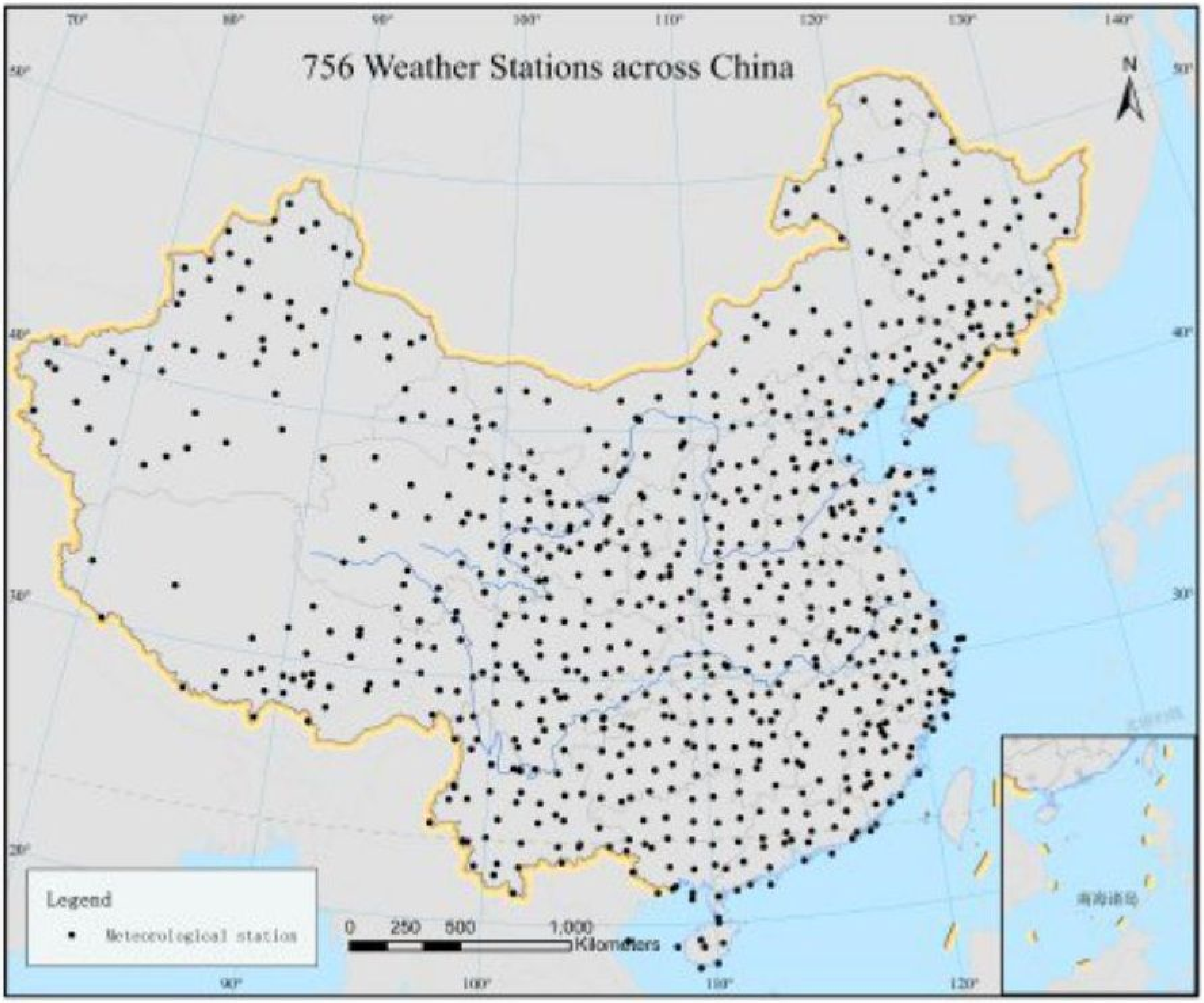

Figure 1

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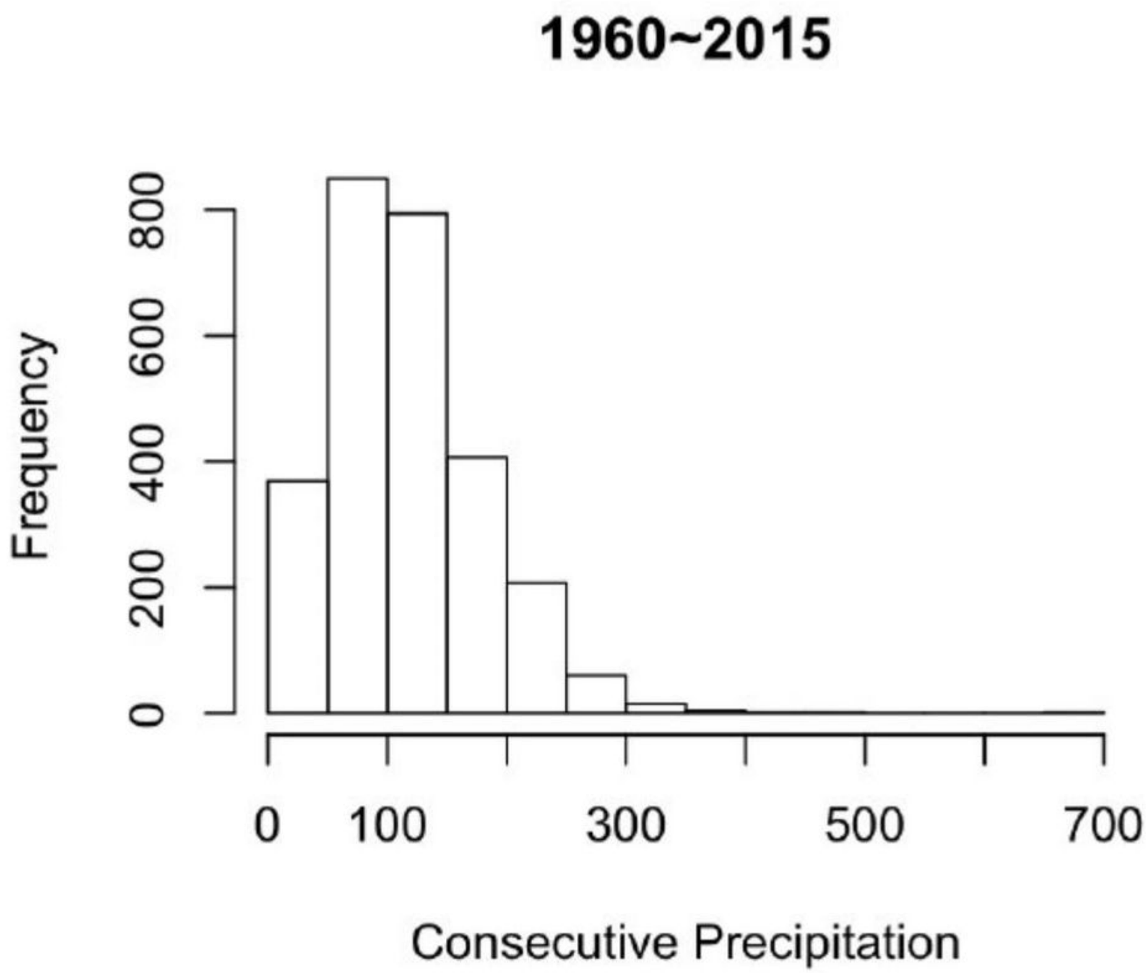

Figure 2

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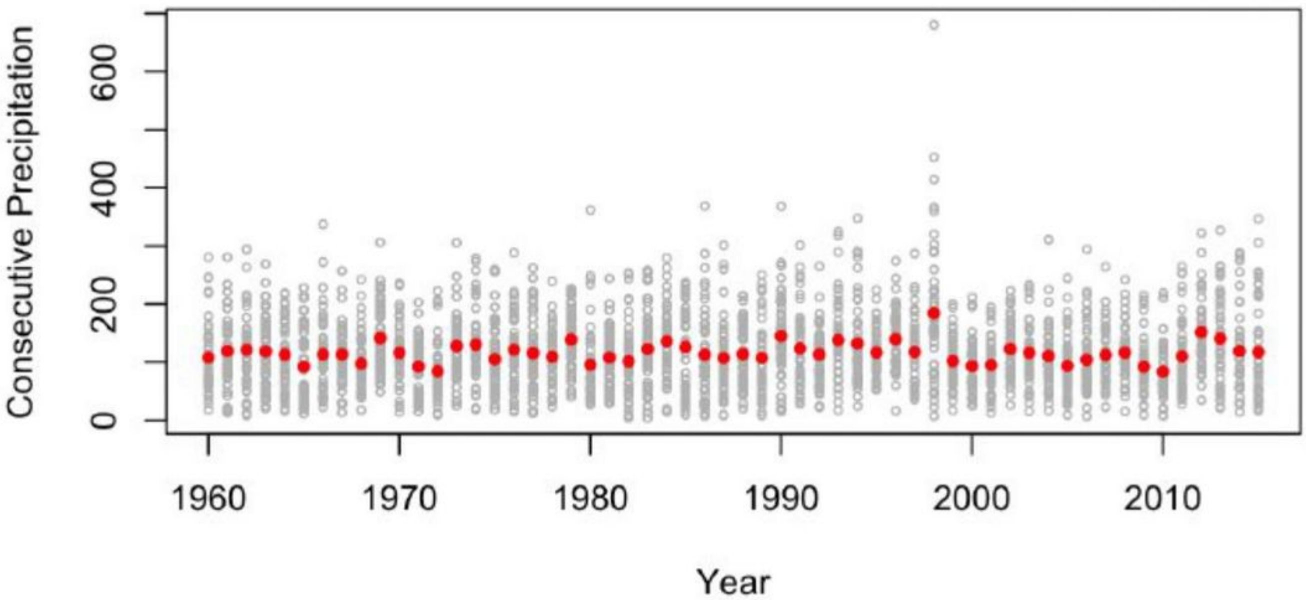

Figure 3

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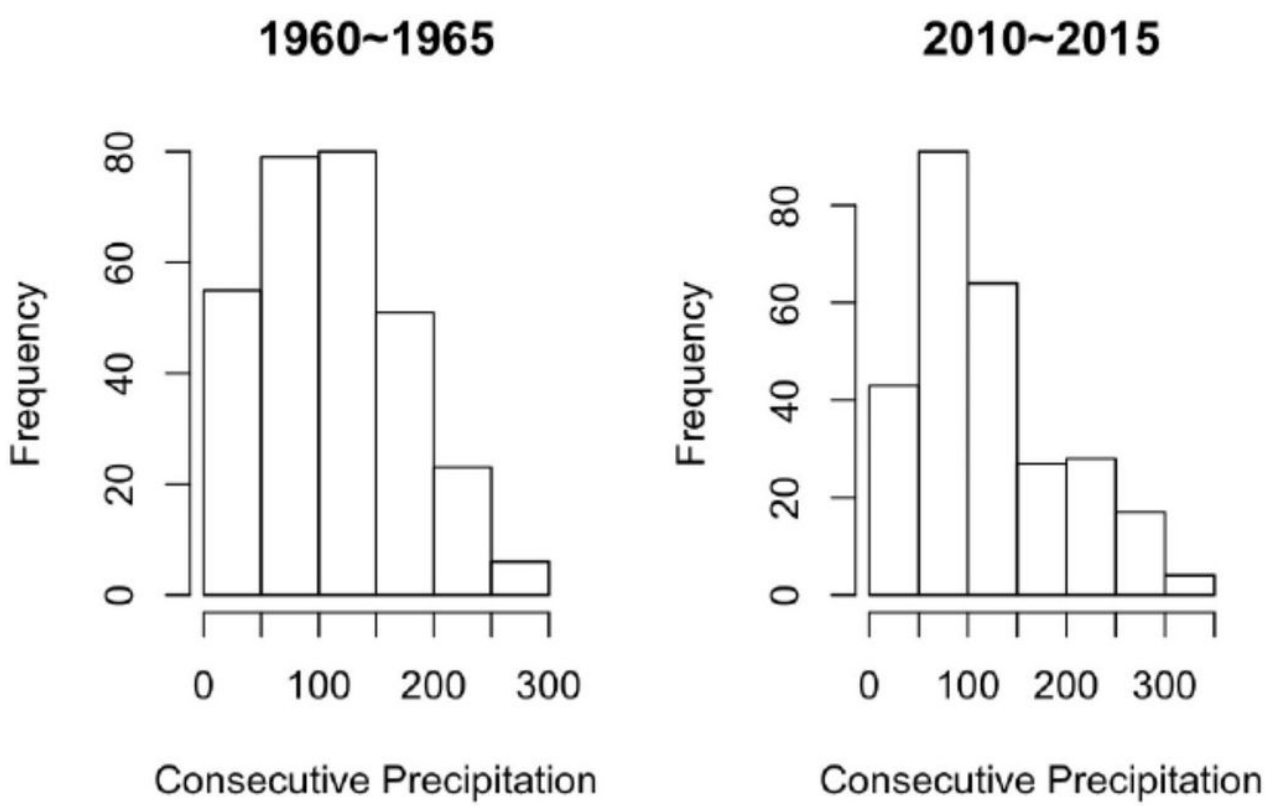

Figure 4

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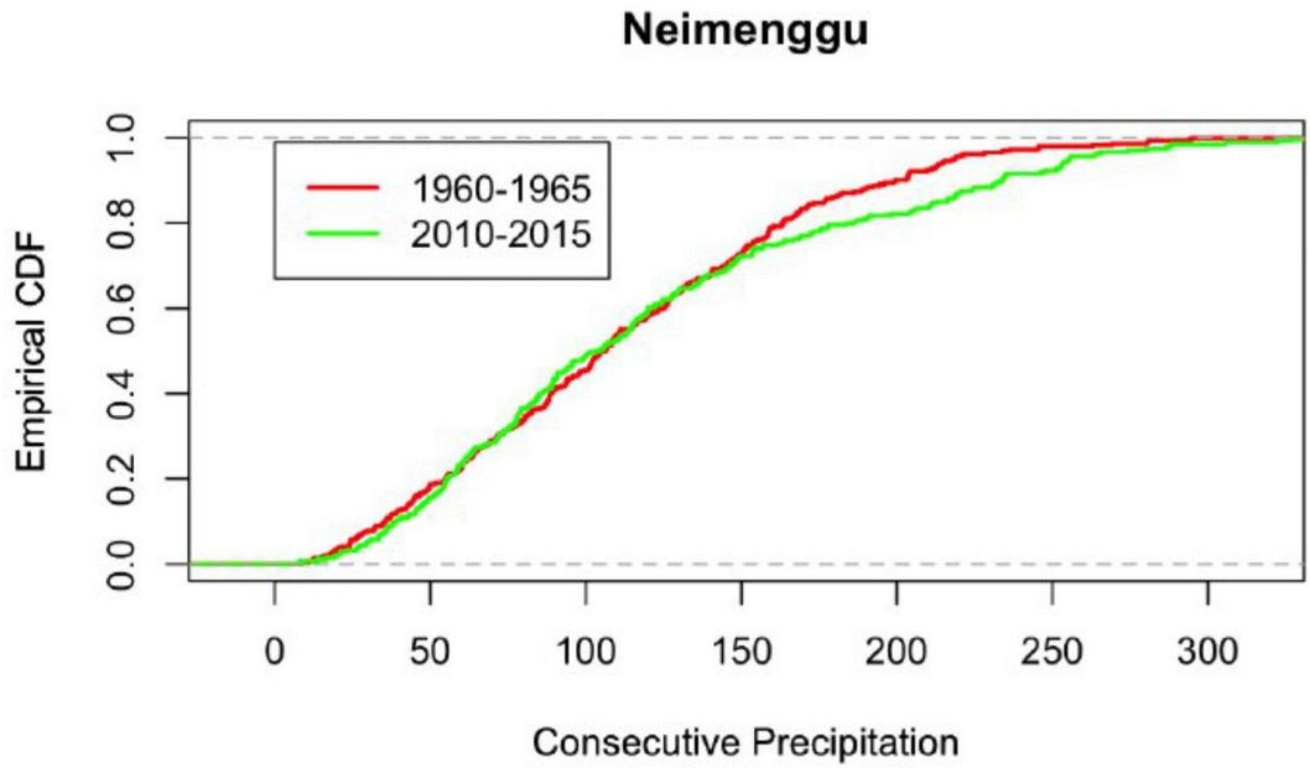

Figure 5

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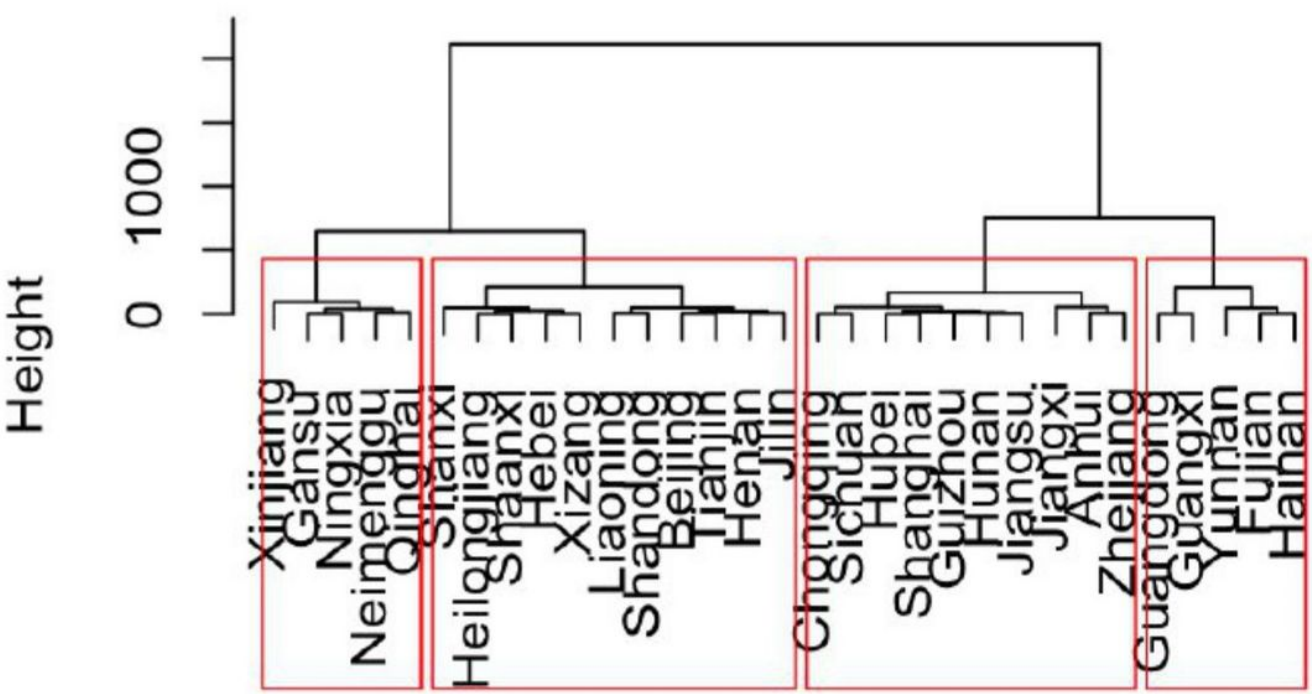

Figure 6

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